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FISH POPULATION AND ELECTROFISHING SUCCESS IN A WARM-WATER STREAM

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This study deals with an enumeration of the fish population in a section of Jordan Creek, a warm-water stream in east-central Illinois, and an attempt to determine the efficiency of the electrofishing method of censusing employed in a 6-year investigation of the dynamics of the fish population. It is part of a long-term study of the ecology of Illinois stream fishes.

Small warm-water streams have received less attention from fishery biologists than have cold-water trout streams. Two especially important aspects of investigation of warm-water streams have been neglected: (1) few censuses of total fish populations have been made, and (2) fish collecting methods have not been carefully evaluated. This relative lack of attention has arisen from early interest and esteem given to trout fishing and from the greater difficulties in adequately working warm-water streams, which usually present a diversified habitat and a large and varied fish population.

Most fish censuses of warm-water streams have been based on estimates calculated from a sample of the population or on the fish populations found in a few selected pools. Both approaches have contributed useful information, some of which, however, has been used in ways not justified by the limitations of the collecting methods.

Methods of collecting fish in warm-water streams are quite diversified (Cleary and Greenbank, 1954). In recent years, stunning fish with electricity has become one of the most widely employed techniques of collecting. Although the various electrical fields used to collect fish have been analyzed and related to physico-chemical conditions of the water or to the physiological responses of the exposed fish, very little has been published on the biological factors influencing the efficiency of the method.

In this paper electrofishing success will be considered as it relates to the behavioral, ecological, and morphological characteristics of the various species of fish present in the stream. Except to describe the aquatic habitat and the equipment employed, the physico-chemical factors influencing electrofishing will not be considered.

Assistance in the field and laboratory was given by William F. Childers, at the time of the study with the Illinois Department of Conservation, and by John M. Schilling, Robert F. Olson, William J. Tucker, and Charles R. Goldman, then with the Illinois Natural History Survey. The willingness of these men to go far beyond their regular working day made possible the rather strenuous censusing procedure employed here.

DESCRIPTION OF STREAM AND STUDY AREA

Jordan Creek drains a glaciated area of 10.6 sq. mi. in southern Vermilion County in east-central Illinois. The stream arises in flat farm and pasture land of rich loam soil. From this flat area the stream flows northward through a 4-mi. section of rolling to rough topography before discharging into the Salt Fork of the Vermilion River (Larimore, *et al.*, 1952). The present study was conducted midway in this lower 4-mi. section of Jordan Creek.

The part of the stream that constitutes the actual study area is about 1 mi. long (5,145 ft.), 23.3 ft. in average width, and 0.58 ft. in average depth as measured at a moderately low water level corresponding closely to the level during the collecting period. It has an area of 2.75 a. and contains 1.60 acre-feet of water. The stream here is characterized by short, moderately deep pools separated by shallow riffles of gravel or bedrock. A stratum of soft sandstone controls the stream gradient at approximately 12 ft. per mi. in this area. Bottom materials are largely gravel, rubble, and bedrock, with sands and silts only in the deeper pools. Mixed hardwoods shade the stream. Water willow (*Justicia americana* (L.)), and water buttercups (*Ranunculus circinatus* Sibth.), are the only common flowering aquatic plants. *Cladophora* occasionally becomes temporarily abundant in the shallow waters.

Thermographs operating immediately downstream from the study area showed that, during the period of field work, air temperatures fluctuated between 55° and 98°F. (mean 75°F.), while water temperatures ranged from 64° to 92°F. (mean 76° F.). These ranges largely represent diurnal fluctuations. Jordan Creek becomes quite turbid for short periods of time but was clear (less than 15 ppm. of suspended solids) during the collecting period. Although water conductivity was not determined at the time of this study, specific resistance measured in previous years during August ranged from 1,760 to 2,160 ohms per centimeter cubed.

The fish population in Jordan Creek was intensively studied in 1950 (Larimore, *et al.*, 1952), at which time 40 species were taken. Since then, four additional species have been collected. In the present study, 33 species and 1 hybrid were taken from the 1-mi. section of stream (Table 1).

PROCEDURE

The methods and equipment employed in this study are described in detail for two reasons: First, the particular techniques of the electrofishing largely determined the collecting efficiency. Second, the electrofishing followed by a rotenone treatment and pumping permitted a virtually complete census of a highly diversified stream fish population in the study area without destroying the downstream population.

The electrofishing gear used in this study consisted of a 30-ft. electric seine powered by a gasoline-driven generator with a maximum capacity of 8.7 amp. of 60-cycle alternating current at 115 v. Drop electrodes of brass welding rods 15 in. long were spaced at 30-in. intervals along the electric seine, creating a voltage gradient between these electrodes of approximately 3.8 v. per in. This figure must be regarded only as the average voltage gradient, for a sharp voltage drop near the electrode surfaces created a complex potential distribution with a lower but uniform gradient in the central one-third of the field between electrodes. A crew of three or four men operated the electric seine and attempted to pick up all fish stunned by the seine that were large enough to stay in a ¼-in.-mesh dip net. The electric generator was moved up and down stream in a small boat equipped with two wheels mounted so as to allow the boat to float in shallow water but to be rolled over rough riffles (Larimore, 1960).

The 1-mi. study area was divided into 11 collecting units, each unit beginning and ending at shallow riffles and including one or more pools. Shocking and collecting was begun at the lower limit of a collecting unit, and the crew worked slowly upstream to the upper limit. One trip through was the extent of electrofishing in shallow areas, but, when the collecting unit included deeper waters, collecting trips were made back down and up again through the area. These repeat collecting attempts are taken into consideration in the evaluation of the efficiency. No nets were put up to block off each stretch because the riffles at the upstream and downstream limits of each collecting unit were shallow enough that few if any fish passed over them during shocking operations.

The game and pan fish collected were moved to another stream; the other fish

were sorted in the laboratory at night. Eight days (between August 8 and 18, 1955) were spent electrofishing the 1-mi. study area.

On completion of electrofishing, the study area was treated with rotenone and drained to allow the removal of the remaining fish. This procedure was possible because of low flow in the stream resulting from very dry weather; the stream flow, which was 6,300 gal. per min. (14 cu. ft. per sec.) at average water levels, had become less than 250 gal. per min.

Needham and Rayner (1939) diverted

TABLE 1.—TOTAL NUMBERS AND WEIGHTS (in pounds) OF FAMILIES AND SPECIES OF FISHES TAKEN FROM THE 1-MI. STUDY AREA, AND THE PERCENT TAKEN BY ELECTROFISHING

Common Name	Scientific Name	Total Population		Percent Taken by Electrofishing	
		Number	Weight	Number	Weight
SUCKERS	CATOSTOMIDAE	1,848	34.01	69	71
Golden redhorse	*Moxostoma erythrurum* (Rafinesque)	84	1.10	81	90
White sucker	*Catostomus commersoni* (Lacépède)	175	15.49	73	71
Northern hog sucker	*Hypentelium nigricans* (LeSueur)	842	7.25	72	69
Creek chubsucker	*Erimyzon oblongus* (Mitchill)	746	8.51	62	70
MINNOWS AND CARPS	CYPRINIDAE	54,098	183.20	52	72
Carp	*Cyprinus carpio* Linnaeus	1	1.66	100	100
Golden shiner	*Notemigonus crysoleucas* (Mitchill)	2	0.06	100	100
Spotfin shiner	*Notropis spilopterus* (Cope)	10	0.13	90	92
Silverjaw minnow	*Ericymba buccata* Cope	879	2.09	86	84
Stoneroller	*Campostoma anomalum* (Rafinesque)	6,501	38.23	82	76
Hornyhead chub	*Hybopsis biguttata* (Kirtland)	809	9.73	74	77
Creek chub	*Semotilus atromaculatus* (Mitchill)	2,027	14.66	72	72
Common shiner	*Notropis cornutus* (Mitchill)	9,431	58.67	69	84
Redfin shiner	*Notropis umbratilis* (Girard)	675	1.38	46	49
Bluntnose minnow	*Pimephales notatus* (Rafinesque)	33,759	58.23	39	55
Sand shiner	*Notropis stramineus* (Cope)	5	0.02	20	50
FRESH-WATER CATFISHES	ICTALURIDAE	1,151	77.27	10	8
Stonecat	*Noturus flavus* Rafinesque	5	0.43	20	23
Yellow bullhead	*Ictalurus natalis* (LeSueur)	1,056	65.63	10	8
Black bullhead	*Ictalurus melas* (Rafinesque)	88	10.61	6	7
Channel catfish	*Ictalurus punctatus* (Rafinesque)	2	0.60	0	0
PIKE	ESOCIDAE				
Grass pickerel	*Esox americanus vermiculatus* LeSueur	311	14.08	75	71
KILLIFISH	CYPRINODONTIDAE				
Blackstripe topminnow	*Fundulus notatus* (Rafinesque)	726	1.62	52	60
SUNFISHES	CENTRARCHIDAE	5,660	130.01	52	51
Hybrid	*Lepomis cyanellus* × *megalotis*	5	0.24	80	83
Smallmouth bass	*Micropterus dolomieui* Lacépède	75	4.64	63	14
Green sunfish	*Lepomis cyanellus* Rafinesque	171	7.79	54	58
Longear sunfish	*Lepomis megalotis* (Rafinesque)	5,310	110.02	53	54
Rock bass	*Ambloplites rupestris* (Rafinesque)	96	7.11	31	27
Largemouth bass	*Micropterus salmoides* (Lacépedè)	3	0.19	0	0
Orangespotted sunfish	*Lepomis humilis* (Girard)	1	0.02	0	0
PERCHES	PERCIDAE	4,784	10.56	35	41
Greenside darter	*Etheostoma blennioides* Rafinesque	391	1.68	65	59
Rainbow darter	*Etheostoma caeruleum* Storer	460	1.46	53	55
Blackside darter	*Percina maculata* (Girard)	32	0.26	41	38
Orangethroat darter	*Ethcostoma spectabile* (Agassiz)	1,158	2.36	38	40
Johnny darter	*Etheostoma nigrum* Rafinesque	1,179	1.65	31	30
Fantail darter	*Etheostoma flabellare* Rafinesque	1,564	3.15	23	32
All Fishes		68,578	450.75	51	54

FIG. 1.—A representative stretch of the Jordan Creek study area, illustrating several habitat characteristics influencing electrofishing success.

the flow of Convict Creek, a California trout stream, and pumped the pools dry in order to collect fish. Other trout streams have been diverted for fish censusing, but the combination of pumps and poison as used in the Jordan Creek fish census employed a somewhat different procedure, which was as follows:

1. Early in the morning, the section of stream to be treated that day was blocked off with ¼-in.-wire-mesh screens.

2. A 3-in. pump was installed and operated immediately above the upstream block. Water from the pump was spread over low pasture land, so that it did not flow back into the creek directly.

3. Another 3-in. pump was set up above the lower screen to pump out a pool in the creek bed to serve as a catch basin for the toxic water that otherwise would move farther downstream.

4. Diluted emulsifiable rotenone (about 1 part Nox-Fish to 30 parts water) was then sprayed on the section beginning at the upper screen and continuing downstream to the lower screen.

5. Fish were collected from the time they first began dying until all that could be found were picked up (usually late in the afternoon). They were taken to the laboratory to be sorted.

6. During the evenings, the two pumps were used to spread the toxic water out over low-lying streamside pasture areas. The larger pools were pumped out, allowed to refill with fresh water, and pumped out again. Because of the dry weather much of this water soaked into the ground. Pump-

ing was continued during the night, so that by the next morning most of the toxic water had been lifted from the creek and the pumps could be moved to the next section of stream.

7. Fish were collecting several times during the second day after poisoning and a check for fish was made on the third day.

This use of pumps for spreading the water over pasture lands to prevent the toxic water from killing fish downstream obviously was much more laborious than it would have been to neutralize the active poison chemically. It did, however, permit a complete fish kill with the introduction of relatively small amounts of poison into the stream, and, more important, it allowed a much greater number of fish to be collected than would have been possible if the treated riffles and pools were running full of water.

COMPLETENESS OF POPULATION CENSUS

This census was probably unique in that it was virtually complete for a relatively long (0.974-mi.) stretch of flowing, warm-water stream with a highly varied habitat and fish population. However, certain probable losses of fish must be considered: (1) some fish killed by shocking may not have been picked up; (2) some fish may have been eaten by other fish as the rotenone began to take effect; or, when dead, (3) some fish may have been eaten by crayfish, water snakes, water birds, etc.; or (4) some may have been hidden under rocks and other cover.

These probable losses of fish deserve further comment and evaluation. The first of these, fish killed by shocking but not picked up, would, according to field observations, consist largely of small minnows. Mortality of suckers was also high, but suckers were more readily seen and collected. The loss of fish killed by shocking but not picked up may have been negligible, however, for most of the fish so severely shocked as to be killed would have been easily seen and picked up.

The second probable loss listed above, the fish eaten by other fish when first affected by the poison, would tend to be small in the Jordan Creek population because of a low proportion of large carnivorous fish. The third probable loss mentioned, fish eaten by crayfish, birds, etc., was minimized by collecting promptly and thoroughly after the fish were poisoned. The fourth mentioned loss, possibly hidden fish, is considered insignificant because careful searches under rocks and roots turned up relatively few fish.

TOTAL FISH POPULATION

The total population removed from the 1-mi. study area consisted of 68,578 fish weighing 450.75 lb., or 24,938 fish averaging 163.91 lb. per surface acre (Table 1). As the average depth of the stream was 0.58 ft., the population was equal to 42,862 fish weighing 281.72 lb. per acre-foot of water.

Minnows (Cyprinidae) were by far the most abundant family (Table 1). They comprised 79 percent of the total number and 41 percent of the weight of all fish taken in the study area. Although bluntnose minnows far outnumbered all other minnows combined, they were matched in total weight by common shiners. The stoneroller was third in both number and weight in the minnow population.

Sunfishes (Centrarchidae) were a poor second to the minnows in the total population. They made up only 8 percent of the numbers and 29 percent of the weight of all fish. Longear sunfish comprised 94 percent of the number and 85 percent of the weight of all sunfishes taken. Their total weight was more than that of any other species of fish.

No other family rivaled minnows and sunfishes in numerical abundance. However, the yellow bullhead was second only to the longear sunfish in total weight (Table 1).

Thirteen crops of minnows, suckers, darters, and small sunfish had been removed previously from the area. The first was taken in August 1950, two were taken in 1951, three each year in 1952, 1953, and 1954, and one in May 1955. In 1953, the yield of minnows alone amounted to 40.645 fish, weighing 243.5 lb. (Larimore, 1955).

TABLE 2.—TOTAL FISH POPULATION TAKEN BY ELECTROFISHING IN SHALLOW (avg. depth < 0.5 ft. and with little water > 1.0 ft. deep) AND DEEP (avg. depth > 0.5 ft. and with considerable amount of water > 2.0 feet) SECTIONS OF JORDAN CREEK STUDY AREA

Depth of Section	FISH PER 100 SQUARE YARDS		FISH PER 100 CUBIC YARDS		PERCENT OF FISH TAKEN BY ELECTROFISHING	
	Number	Pounds	Number	Pounds	Number	Weight
Shallow	513	2.7	3,645	16.2	67	71
Deep	324	4.5	1,404	18.9	44	45

This 1953 yield, taken over a 5-month period, weighed 1.3 times as much as the total minnow population in the August 1955 census reported in this paper.

In May 1955, 3 months before the total census was made, the following fish were removed: 6,593 minnows weighing 43.96 lb., 174 suckers weighing 8.14 lb., 1,113 darters weighing 3.78 lb., 797 small sunfish weighing 7.24 lb. The above species along with miscellaneous species totaled 8,791 fish weighing 63.27 lb. This weight was equivalent to 14 percent of the pounds of fish removed in the total census of August.

The shallow sections of the Jordan Creek study area yielded larger numbers but fewer pounds of fish than did the deep sections (Table 2). A comparison is made in Table 2 of the fish population expressed as numbers and pounds in square yards and in cubic yards.

In pounds per acre, the population of Jordan Creek is within the range of that found in many other warm-water streams (Table 3). Much larger populations (by weight) have been reported, but an examination of collecting techniques employed indicates that the sample areas may have included large concentrations of fish that were not representative of the stream as a whole.

An attempt to evaluate further the Jordan Creek population revealed many of the difficulties of comparing the published inventories of stream fishes (Table 3). Collecting methods and equipment were different for the various published studies, as were the units used in expressing numbers and weights of fish. Some censuses included all species, others included only the larger species or individuals. Some samples included fish from a long stretch of stream and represented most of the habitats present, whereas others were taken from an area not generally representative of the stream and contained either an abnormally high or low fish population. The uneven distribution of fish in most streams makes the selection of sampling sites of primary importance and may largely account for the tremendous range in population sizes that has been reported. These comments are not intended as criticisms of work that has been done, for each stream requires a special approach and imposes definite limitations on what can be done. However, this lack of uniformity must be recognized by those interested in comparing published results and by those investigating and reporting populations of stream fishes.

EFFICIENCY OF ELECTROFISHING

The efficiency of the electric seine, as measured by fish taken in the subsequent poisoning-pumping operation, was very different for different families and for different species in the same family. Efficiency of electrofishing was determined by the ability of the shocker to stun fish, and the collector to see and collect the fish. Also, efficiency was directly affected by behavior, habitats, and morphological characteristics of each fish species.

Sucker Family

Sixty-nine percent of the sucker population in the Jordan Creek study area were taken with the shocker. Only in the pickerel family was as high a proportion of the total population collected by shocking. Collecting efficiency was high because suckers are relatively large (even the young are large

TABLE 3.—SOME QUANTITATIVE CENSUSES OF FISH POPULATIONS IN WARM-WATER STREAMS

Reference	State	Stream	Number of Samples	Pounds per Acre	Collecting Method
Thompson and Hunt, 1930	Ill.	Countywide	132	150	Seine
Eschmeyer and Clark, 1939	Mich.	Big Mud Creek	1	166.2	Block and poison
		Little Mud Creek	1	65.9	
Roach, 1948	Ohio	West Shade River	2	66.4	Poison
Gerking, 1949	Ind.	Paw Paw Creek #1	4	96	Block and seine
		Paw Paw Creek #2	5	86	
		Little Blue River #1	5	169	
		Little Blue River #2	5	939	
		White Water River	5	52	
		Simon Creek	5	46	
Swingle, 1954	Ala.	Coosa River	4	89.8[1]	Poison
		Tombigbee	3	931.8[2]	
		Black Warrior	1	1,069.9	
		Tallapoosa	1	45.7	
		Tensaw	1	1,544.6	
Sullivan, 1956	W. Va.	Lost River	1	91[3]	Block and shock
		Mill Cr. (Hampshire Co.)	1	169	
		Lunice Creek	1	170	
		Lost River	1	203	
		Tygart River	1	183	
		Mudlick Run	1	219	
		Patterson Creek	1	150	
		North River	1	68	
		Tilhance Creek	1	173	
		Mill Creek (Grant Co.)	1	278	
		South Fork River	1	64	
		So. Branch of Potomac R.	1	267	
		North Fork River	1	115	
		Back Creek	1	49	
		Little Cacapon River	1	56	
		Sleepy Creek	1	32	
Charles, 1957	Ky.	North Fork River	5	162	Block and poison
		Whippoorwill Creek	3	15	
		Floyd's Fork Creek	8	68	
Present study	Ill.	Jordan Creek	1	163.9	Block, shock and poison

[1] Includes one polluted sample area with only 8.3 lb. per acre.

[2] Includes one cutoff sample area with 1,859.4 lb. per acre.

[3] The West Virginia studies include "only the larger, more important species," and all but the first are for pool areas only.

enough by August to be easily seen); species inhabiting deep water are light colored and easy to see, while camouflaged species are usually taken in shallow water. Except for the chubsucker, suckers are generally in open pools or riffles rather than under concealing cover.

Table 4 shows the relationship of various favorable factors to the efficiency of collecting the several species of suckers, and percentages of these kinds of suckers taken by electrofishing in Jordan Creek.

Golden Redhorse.—The redhorse was second among all species in percentage of numbers and first in percentage of weight taken by electrofishing; the take of redhorse was high because schools were in open water over clean bottoms, where they were readily stunned and easy to see. The redhorses present were young-of-the-year or yearlings and were not associated with the deepest water, as adults of this species might have been. Redhorses were taken by electrofishing in all 11 of the separate collections, but were found in only two poisoning collections. All but one poisoned fish came

TABLE 4.—CHARACTERISTICS OF FISHES AND OF THE FISHES' HABITATS THAT HAVE A FAVORABLE INFLUENCE UPON EFFICIENCY OF ELECTROFISHING, AND RELATIONSHIP OF THESE FACTORS TO ACTUAL TAKE BY ELECTROFISHING OF FOUR SPECIES OF JORDAN CREEK SUCKERS

Species	Fish Characteristics			Habitat Characteristics			Total Favorable Characteristics	Percent Taken by Electrofishing
	Large Size	Large Young	Bright Color	Shallow Water	Smooth Bottom	No Vegetation		
Redhorse	×	×	×		×	×	5	81
White sucker	×	×	×		×		4	73
Hog sucker	×	×		×		×	4	72
Chubsucker				×	×		2	62

from the same pool, suggesting that a school was missed when shocking was done there. Except for 15 missed in one pool, electrofishing took 99 percent of the redhorses present.

White Sucker.—In response to electrofishing, the white sucker was similar in most respects to the redhorse except for a number of large adults that were in deep pools and more difficult to collect; also this species was more closely associated with vegetation.

Hog Sucker.—The hog sucker was taken by electrofishing in virtually the same percentage as the white sucker but for different reasons. The camouflaged, dark-bodied hog suckers were difficult to see but were generally found in moderately shallow waters where they were easy to pick up. There was a much larger number and percentage of the young of this species than of any other sucker, but the young were large enough (1.7–2.8 in., total length) to be collected easily.

Creek Chubsucker.—This species was lowest among the suckers in percentage of numbers collected by electrofishing, a result of being difficult to see and pick up in silty backwaters and weed beds. Shocking took a higher proportion of adults than of the more abundant young-of-the-year (1.5–2.5 in. in total length).

Minnow Family

Although most minnows in Jordan Creek were found in large aggregations in moderately shallow waters, where they were easily picked up, only 52 percent of their numbers were taken by electrofishing. This moderately low collecting rate was related to the presence of large numbers of very small fish.

Silverjaw Minnow.—Through electrofishing, a higher percentage of silverjaws was taken than of any other species represented in the collections by more than 10 specimens. These minnows were found mostly in shallow, sunny, smooth-bottomed areas where they were easy to see and pick up. Although some young-of-the-year were very small (less than 1.5 in. in length), their number was not sufficient to lower noticeably the efficiency of the shocker. Their shiny white color also aided in collecting.

Stoneroller.—This minnow was second most numerous and second in rate of electrofishing efficiency for all species in the study area. They were taken in shallow areas over clean bottoms. The young were not too small (1.7–2.2 in. in total length) for easy collecting.

Hornyhead Chub.—Electrofishing took 74 percent of the hornyhead chubs present; although generally large minnows, some of the young-of-the-year were less than 1.7 in. long. Adults frequently were around root masses and similar cover where they were difficult to collect.

Creek Chub.—This chub was similar in most respects to the preceding species.

Common Shiner.—Collecting efficiency for this minnow was 69 percent of numbers and 84 percent of weight, a fact which indicates that the take was highest for large adults. The shiny body color and preference for clean bottoms aided in collecting. Common shiners generally inhabited somewhat deeper waters than other minnows,

but their smallest young (1.3 in.) were usually in shallow areas.

Redfin Shiner.—This shiner was taken at a relatively low collecting efficiency because of a proportionately large number of small young present with only a few large adults, and because of the preference of this minnow for soft bottoms and vegetation bordering deep water.

Bluntnose Minnow.—An abundance of small bluntnose minnows (ranging to less than 1 in.) accounted for the very low collecting efficiency. A higher collecting rate by weight than by numbers also indicated the inefficiency of taking the small young. Bluntnose minnows were found abundantly in a wide variety of habitats, so that it was difficult to draw a relationship between habitat and electrofishing success.

Catfish Family

Nearly all factors that have been previously mentioned as lowering the efficiency of electrofishing are associated with members of this family; these negative factors have resulted in a very low efficiency (10 percent of numbers) in collecting. Catfish are dark-colored; the adults are found below undercut banks or other cover, usually in deep water; they make little movement on being stunned and seldom float to the surface.

Yellow Bullhead.—This species was captured by electrofishing at a very low efficiency rate for reasons given above for the family. Because their color is black, the small young scattered along riffle areas are only slightly easier to collect than the adults in pools. Inasmuch as yellow bullheads were second only to the longear sunfish in total weight taken from the study area, the electric shocker obviously was of little value in collecting them.

Black Bullhead.—There were proportionately fewer young of this species to be collected easily in shallow water than of the yellow bullhead; consequently the collecting efficiency by number was slightly lower than for the yellow bullhead. Otherwise, similar conditions made collecting difficult for both species.

Sunfish Family

The cover-seeking habits and generally dark body color of the members of this family caused the electrofishing efficiency to be relatively low. On the other hand, most of them were large enough to be easily picked up. They often gave a spasmodic forward lurch on being stunned, and their closed air bladder caused some of them to float.

Smallmouth Bass.—Few large smallmouths were in the study area at the time of the census. Our failure to take several of the larger ones during electrofishing resulted in a very low efficiency rate by weight but a fairly high one by numbers. Although usually found in deeper pools and within the cover of boulders and root masses, smallmouths often moved ahead of the electric seine and became vulnerable to shocking in the more shallow areas of a pool.

Green Sunfish.—Their dark body color, small size of young, and preference for concealing cover lowered collecting efficiency for this species.

Longear Sunfish.—Longears comprised nearly twice the weight of any other species taken in the study area. Although there were more young-of-the-year longears than green sunfish, body color of the longears was more readily visible in water.

Rock Bass.—In spite of their greater average size than any other centrarchids in the collections, rock bass were taken at a low efficiency rate. This was due to their dark color and their preference for shaded areas and dense vegetation cover.

Perch Family

In the Jordan Creek study area this family was represented by six species of darters. They were generally difficult to take by electrofishing because of their small size, their bottom-dwelling habits, and their rudimentary air bladder which allowed them to sink quickly to the bottom. Bright colors and shallow-water habitat characteristics facilitated the collecting of a few species in this family.

Greenside Darter.—The greenside darter

was taken at the highest rate of collecting of any species in the family. This rate was high because it was one of the largest darters present, was generally bright colored, and was found in clean, shallow riffles.

Rainbow Darter.—In response to electrofishing, the rainbow was similar to the preceding darter, but the rainbow was of smaller size.

Blackside Darter.—This species was one of the largest darters present; it had fairly conspicuous body color, and was generally found over smooth bottoms. The lower rate of collecting efficiency for this darter was related to the deeper water it inhabits.

Orangethroat Darter.—This species was often found in small gravels of shallow, sunny riffles. The small size and the fact that many orangethroats were drab-colored females or immature fish made collecting inefficient.

Johnny Darter.—The small size, no bright colors, and preference for moderately deep water of this species resulted in low collecting efficiency, although smooth, sandy bottom aided somewhat.

Fantail Darter.—Collecting efficiency for this species was lowest of any darter and lowest among all other species, except for catfishes. Low rate was caused by its small size, dark drab color, and often being among vegetation and organic debris.

Miscellaneous Species

Grass Pickerel.—The pickerel was second only to the redhorse sucker in its high rate of electrofishing returns. Pickerel, although usually associated with aquatic vegetation, were readily taken because they were easily stunned and were large enough to be seen easily. They often moved out of vegetation before being shocked or lurched into view as they were stunned.

Blackstripe Topminnow.—The small size and surface-swimming habit of this species made it difficult to stun and collect. Although topminnows did not float after being shocked, they were usually near the surface when shocked and thus were easily seen and collected. Their white undercolor often made them visible when stunned.

DISCUSSION OF EFFICIENCY

Such studies as those of Haskell and Zilliox (1941) and Schuck (1945) in trout streams revealed that size of fish was probably the most important influence on electrofishing with direct current. Fleener (1952) found that electrofishing with alternating current in a western trout stream was affected by such variables as water velocity and volume, overhanging banks, and brushy stream areas. Observers working in warm-water streams generally agree upon the importance of fish size and the factors mentioned by Fleener, but also have listed other influencing conditions. Funk (1949) listed the following physical factors in order of their decreasing influence upon the efficiency of collecting fish with an alternating current shocker: turbidity, depth, type of bottom, and velocity of stream. He found various forms of cover to be important, too. Sullivan (1956) referred to fish size, stream width, and available cover as influences on electrofishing with direct current (and observed the same with alternating current) in West Virginia streams. In all these studies, mark-and-recapture procedures showed no consistent rate of collecting efficiency in the various waters and revealed rather large differences in the rate of capturing various species.

The most common procedure for calculating collecting efficiency in a stream has employed the mark-and-recapture method in which part of the fish population is marked and released, then the area is reworked and, from the ratio of marked to unmarked fish, the proportion of the total population collected the first time is determined. This method has been successfully used in trout streams to determine collecting efficiency and total fish population, but in our warm-water streams, with their more complex habitats and fish populations, many complications of the method have been encountered.

To begin with, it is a tremendous task to obtain a reliable estimate for each species in a population composed of 30 or 40 different species, especially when many of these

are such small fish as to be difficult to handle without inducing high mortality. Another complication is that fish previously missed and fish previously captured and marked may not be of equal vulnerability to capture. It has been suggested (Holton and Sullivan, 1954) that fish tend to avoid the electric field after once being shocked, although other studies have not confirmed this. On the other hand, fish that are in a difficult place for collecting the first time may be in just as difficult a situation for collecting the second time. Such basic unknown influences as these, which would push a population estimate in opposite directions, pose serious questions as to (1) the reliability of the method in a highly varied habitat, and (2) the practicability of the method when dealing with a large number of different species of fishes.

The simplest, but not necessarily the easiest, approach to determining efficiency is to use other methods to collect those fish missed while shocking. Other methods include poisoning the fish remaining in the area worked, or draining individual pools in a representative stretch of the total area, or both poisoning and draining. Many problems arise here, too. Because of its limitations, the follow-up census might not be complete; it might be undesirable because it would destroy the population being studied; under some circumstances, it might severely damage the population downstream.

In the discussion of factors affecting electrofishing in Jordan Creek, it may have become evident that no matter what factors favor or hinder collecting, any one factor might overshadow all the others. For example, a very low percentage of bullheads was taken by electrofishing; as long as bullheads remain concealed below undercut banks, even the light-colored, easily visible bellies of these fish do not aid in collecting. In general, however, the relative influences of many factors determine the collecting rate (Table 4).

No definite efficiency factor can be established for general use, even for a single species in a single stream. Collecting efficiency will be different in various areas of the same stream because of habitat variations, and efficiency will vary for a single species because the species occurs in a number of habitats. Any estimate of a total fish population based on electrofishing in a stream as varied in habitat as Jordan Creek must be made with caution and with recognition of the influencing conditions.

Each stream, each habitat, and each species present particular problems. These problems must be recognized in order to avoid errors or misinterpretations in making a quantitative evaluation of a stream population.

SUMMARY

An electrofishing census was made of the fish in a 1-mi. section of Jordan Creek, a small warm-water stream in east-central Illinois. The stream flow was then diverted with pumps and the fish missed in electrofishing were poisoned and collected. This procedure permitted a virtually complete census of a highly diversified fish population and made possible an evaluation of certain biological factors influencing electrofishing in a varied stream habitat.

The fish population was 24,938 fish weighing 163.91 lb. per surface acre of water, or 42,862 fish weighing 281.72 lb. per acre-foot of water. The minnow family was the most numerically abundant, and longear sunfish made up the maximum total weight for any one species in the population. Shallow sections produced greater numbers of fish but less weight per unit of area or volume of water than did deep sections.

Efficiency of electrofishing was directly affected by the behavior of each species, by their habitats, and by their morphological peculiarities. No definite efficiency factor for the electric shocker can be established for general use in a stream with such a highly diversified fish population and habitat as Jordan Creek.

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AN ECOLOGICAL STUDY OF TREE CAVITIES AND GROUND BURROWS IN FOREST STANDS[1]

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In forested areas, cavities in trees and logs, and burrows in the ground form escape and nesting cover that may be used by many small mammals and some birds. The kind and number of these cavities and burrows may be related in part to forest type and stand condition. Objectives of this study were to determine the number and size of the cavities and burrows in different forest stands, to determine environmental relationships, and to indicate the amount of animal use. The study was made in four different stands in the beech–maple type and in two stands in the oak–hickory type. Stand differences were due primarily to varying degrees of cutting and grazing.

Most of the cavities in hardwood trees which are used by animals develop from decay which starts near the junction of a limb and the main tree trunk. Baumgartner (1939) describes the process of cavity formation as starting with natural pruning and subsequent stub and heartwood decay. Squirrels, other mammals, and birds may gradually clean out the rotted pulpy material. Squirrels also continually gnaw many

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of the cavity entrances, often maintaining openings large enough for their use. Cavities may also develop from trunk wounds or from woodpecker holes (Allen, 1943). They may occur in many tree species; elm, soft maple, and beech are listed most frequently.

From a study of ground dens in southern Michigan, Allen and Shapton (1942) concluded that most were constructed by woodchucks. Other animals may do some of the digging; badgers dig deep, long burrows, and both the red fox and striped skunk either dig their own burrows or use those of other animals (Burt, 1957).

DESCRIPTION OF FOREST STANDS

The stands were selected on the basis of conditions which resulted from forest management or from no management. The boundaries were determined by the extent of the condition class on a specific site. These stands, which were in different woodlots, varied in size from 4 to 8 a.

Beech–Maple Type

Four stands that were selected on the Michigan State farm property south of the campus at East Lansing are located in woodlots which vary from 12 to 60 a. in area. All are on undulating to gently rolling lands. For this study, the stands are named according to the management practices which affected present conditions.

The managed stand (6.2 a.) is well stocked and has both all-aged and even-aged groupings, due in part to two improvement cuts, one in 1938 and one in 1948, which removed most of the trees classed as poor growing stock or cull. The trees, which generally range from 6 to 20 in. d.b.h., have little rot or crown deterioration. Approximately half of the number of stems and half of the basal area are sugar maple (*Acer saccharum*). American basswood (*Tilia americana*), American beech (*Fagus grandifolia*), white ash (*Fraxinus americana*), and northern red oak (*Quercus rubra*) are important associate species. The soil type is Hillsdale sandy loam.

The old-growth, unmanaged stand (8.2 a.), also on Hillsdale sandy loam, has been uncut and ungrazed. It is a well-stocked, all-aged stand with straight boles and well-formed crowns. Sugar maple and beech make up most of the stand in sizes ranging up to 40 in. d.b.h. Here most of the cavities developed in over-mature and mature trees in the upper boles and in enlarged bases.

In the cut, unmanaged stand (4.8 a.), some of the large good growing stock of maple, beech, and white ash was cut in 1925 and 1930. The remaining stand is still all-aged and well-stocked, largely with sugar maple and some beech; however, the proportion of trees with decay in the boles and crown is relatively high, especially the beech. Enlarged bases are common on the large trees, often with cavities extending into the bole. A remarkable development in this stand is the large number of burrows in the sandy surface soil of the Spinks loamy sand.

In the cut, grazed, unmanaged stand (4.1 a.), sapling and small pole sizes were missing and the overstory trees, especially the beech, had a large amount of rot in boles and crowns. Approximately one-half of the number of stems and two-thirds of the basal area are sugar maple; important associate species are beech, white ash, American elm (*Ulmus americana*), and basswood. The soil type is a Miami loam.

Oak–Hickory Type

The woodlots in this type are located at the Rose Lake Wildlife Experiment Station 10 mi. northeast of East Lansing on well-drained upland sites on Kalamazoo sandy loam.

The old-growth, unmanaged stand (4.2 a.) has a main overstory of old white oaks (*Quercus alba*), many 200 to 300 years old, and some black oak (*Quercus velutina*), generally smaller and younger than the white oak. Crowns of many white oaks are large and the boles of some are crooked or leaning. Stubs of large dead limbs often remain attached to the boles.

The managed stand (5.1 a.) is even-aged and approximately 120 years old. Black oak is the dominant species in the stand;

white oak and pignut hickory (*Carya glabra*) are minor components. The stand is well-stocked even though it was partially cut in 1948. Boles are generally straight and crowns small. Some of the boles are clear; on others the dead branches are small or the small branch stubs are almost completely healed over.

METHODS

In each stand, all bole and limb cavities which had outer diameters ½ in. and larger and which appeared to be adequate in size for animal use were examined and measured. Trees were observed from the ground with binoculars and also at varying heights by climbing. A separate systematic search was made for cavities in the base of trees. Ground burrows with outer diameters 4 in. and larger were examined and measured. Smaller burrows which were used by chipmunks were numerous in the oak–hickory stands. These were difficult to see and count accurately and were not tallied. Counts of squirrel leaf and twig nests in good repair were made.

A rope and saddle were used for climbing. To facilitate the placement of the rope for high climbing, a bow fitted with a fishing reel and a casting line attached to a weighted arrow was used (Gysel, 1960). Measurements were made in all cavities with a flexible steel tape and a long flexible probe. Lights which could be directed into a cavity or lowered into it were used to determine the shape of the interior and possible use by animals. A small periscopic device was developed to allow the observer to look up or down inside the cavity. Automatic cameras were used at entrances of most of the burrows and cavities at the base of trees in the beech–maple stands to determine species of animals using the burrows or cavities (Gysel and Davis, 1956).

The following measurements and observations of the cavities and burrows were made: Diameter at entrance; diameter of inside horizontal cross section; vertical extent above and below the entrance; height of cavities from ground; origin; evidence of use by animals from close observation; appearance of cavities from the ground (in

TABLE 1.—DENSITY AND PROPORTION OF 989 TREE CAVITIES AND BURROWS, AND 51 LEAF NESTS ACCORDING TO ORIGIN IN EACH STAND

Tree Cavities, Burrows, and Nests According to Origin	Beech–maple Stands								Oak–hickory Stands			
	Managed[1]		Old-growth, unmanaged[1]		Cut, unmanaged[1]		Cut, grazed, unmanaged[1]		Managed[1]		Old-growth, unmanaged[1]	
In tree boles												
Limb scars	11.7	51	27.4	62	19.9	44	34.9	61	5.0	54	10.0	64
Lightning scars, frost cracks, split sections, open rot above base	2.2	10	4.1	9	6.9	15	8.5	11	0.4	4	0.6	4
Scars and crevices in enlarged bases	6.3	27	9.0	20	6.7	14	8.0	14	0.6	6	2.8	17
Unknown origin	0.2	1	1.3	3	2.2	5	2.6	4				
Woodpecker holes			1.0	2			2.2	4	0.2	2		
Hollow logs	0.3	1	0.2	0.5	1.5	3	0.5	1				
Animal excavations in the ground	0.2	0.5	0.1	0.3	3.9	9	2.2	2.5	0.4	4		
Squirrel leaf nests	1.9	9	1.2	3	4.6	10	1.5	2.5	2.7	30	2.8	17
Totals	22.8		44.3		45.7		60.4		9.3		16.2	

[1] Left-hand column shows average number per acre; right-hand column shows percent.

regard to possible use by fox squirrel or raccoon). The following additional measurements were made on trees with cavities: Tree species; diameter; crown position; vigor and risk class.

My estimate of animal use of cavities and burrows was based on many kinds of evidence. Sometimes the animal was present in the cavity; generally, however, the observer determined animal use by the presence of scats, hair, feathers, fleas, odors, nesting materials, partly eaten or chewed seed parts, seed husks, and amount of wear on the sides of the cavity opening. The amount of chewing was always noted, but was not used as a criterion of cavity use because squirrels chewed on all sorts of scars and wounds. Observations were made during the spring and fall for a period of 3 years. Most cavities were closely observed once; however, some were checked two or three times.

An indication of animal numbers in the stands was obtained by live-trapping in each of the beech–maple stands during the summer and fall, 1958 and 1959. In the oak–hickory stands, the regular fall trapping data obtained by the Rose Lake Wildlife Experiment Station personnel were used.

RESULTS

A total of 989 cavities and burrows were measured and observed in all the stands (Table 1); they made up most of the escape cover, i.e., dens which remain intact in the deciduous stands throughout the year. Leaf nests, which were also counted, are less permanent. The only cover materials not considered were leaves, branches, and dead materials other than logs on the ground, and burrows smaller than 4 in. in diameter.

A large number of cavities of potential use to wildlife were formed from limb scars in all stands. The proportions of limb-scar cavities to other kinds were similar in the different stands even though the actual number of cavities varied greatly. Cavities which developed from scars, cracks, and other types of wounds on the tree boles above the base were less numerous. Cavities at the base of the boles occurred mainly in beech–maple stands. Only a small number of openings were developed by woodpeckers, generally in old trunk stubs or in dying portions of the tree crowns.

Ground burrows were few and well-scattered, except in the cut, unmanaged stand; here they were exceptionally numerous.

Hollow logs, mainly beech and maple, provided a small amount of cover in the beech–maple type. All were from large wind-thrown trees.

Cavities in Tree Boles above the Bases

Number and distribution by entrance diameters.—In the beech–maple type there is a noticeable difference in the number of cavities in managed and unmanaged stands (Table 2). In the old-growth and cut, unmanaged stands there were 34 and 28 cavities per acre, respectively, mostly in mature and overmature trees. In the grazed

TABLE 2.—AVERAGE NUMBER OF CAVITIES PER ACRE IN TREE BOLES ABOVE THE BASE ACCORDING TO ENTRANCE DIAMETERS

Stands	Entrance Diameter (inches)				
	0.5–1.9	2.0–3.9	4.0–5.9	6.0+	Total
BEECH–MAPLE					
Managed	5.0	7.7	0.6	0.5	13.8
Old-growth, unmanaged	6.6	17.8	7.3	2.3	34.0
Cut, unmanaged	4.0	15.5	4.0	4.7	28.2
Cut, grazed, unmanaged	7.6	28.5	7.3	4.4	47.8
OAK–HICKORY					
Managed	2.7	2.4	0.4	0.2	5.6
Old-growth, unmanaged	2.5	8.3	0.3	0.0	11.1

stand the 48 cavities per acre were mainly in trees of poor vigor. The managed stand with 14 per acre is a distinct contrast. During the original reconnaissance in the managed stand in late summer, there appeared to be no cavities; some were located during a ground check with glasses in winter and more were found when the trees were climbed.

The small number of cavities in the oak–hickory stands is a marked contrast to the number in the beech–maple stands. In the old-growth oak–hickory stand many stubs of naturally pruned limbs remained on the trees or the limb scars healed over. In the younger managed stand, most of the limb scars from naturally pruned branches were small and had healed over quickly. From the ground it was difficult to see the few small cavities in the stand without field glasses.

The large proportion of cavities in the 2–4-in. class was due to the size of the limb scars resulting from natural pruning and apparently to gnawing of squirrels which often prevents reduction in hole size. This proportion was remarkably consistent in the four beech–maple stands; it varied from 50 to 60 percent of the total number of cavities in the tree boles in each stand.

Cavities 4 in. in diameter and larger occurred mainly in the unmanaged beech–maple stands predominantly in old-growth and poor vigor trees.

Horizonal cross-section diameter of cavities.—In unmanaged stands, the pattern of cavity development was remarkably uniform (Fig. 1). Approximately 70 percent of the cavities were greater than 2 in. in diameter, and were of potential value for the various animals utilizing the tree boles and crowns. From 24 to 33 percent of the cavities in the old-growth stands and in the cut, unmanaged stand were 6 in. in diameter or larger.

In the two managed stands 44 and 49 percent of the cavities were less than 2 in. in diameter. Most of these cavities were probably not usable by animals; however, larger cavities will probably develop from some of them in the future.

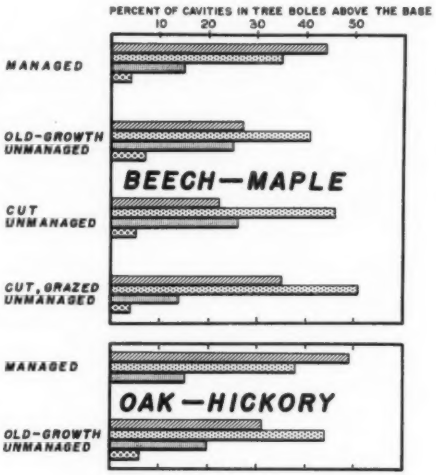

FIG. 1. Horizontal cross-section diameters of cavities in tree boles above the bases as related to stand management.

Vertical extent of cavities.—The pattern of vertical cavity development was generally similar to that of the inner cross-section diameter (Fig. 1); however, the extent of cavity development was greater vertically than horizontally. In the old-growth and unmanaged stands approximately 75 percent of the vertical measurements were greater than 2 in.; 48 to 63 percent of these measurements were greater than 6 in. In the managed stand, however, approximately 50 percent of the cavities were less than 2 in. in vertical extent.

Ordinarily the amount of vertical development of a cavity was approximately proportional to the inner diameter. Therefore, a cavity with a horizontal cross-section diameter large enough to accommodate an animal was generally adequate in size vertically.

Height from ground.—The majority of tree bole cavities were formed within or just below the live crown area. The height of cavities was therefore related to crown heights. In five of the stands in which the

height of the dominant and codominant trees varied from 70 to 80 ft., cavity development most commonly occurred from 20 to 40 ft. above ground. In the old-growth stand where many of the dominant and codominant trees were 90 to 100 ft. in height, 63 percent of the cavities were over 40 ft. and 30 percent were over 60 ft. from the ground.

Diameter of trees.—Cavity development generally occurred in large trees. In all stands other than the old-growth beech–maple, 70 to 75 percent of the cavities occurred in the 12- to 24-in. diameter class; in the old-growth stand 39 percent of the cavities developed in trees 24 in. d.b.h. and over.

Tree vigor.—Cavity development most commonly occurred in trees of poor vigor. In the unmanaged beech–maple stands from 65 to 85 percent of the cavities were in trees tallied as poor growing stock or cull, generally trees with dead and dying branches in the crown and/or moderate to heavy rot in the boles. However, in the two managed stands 50 to 75 percent of the cavities occurred in trees classified as good growing stock.

Tree species.—In the beech–maple type, the number of cavities per tree species was approximately proportional to the basal area of each species in the stands. From 40 to 60 percent of the cavities developed in sugar maple and approximately one-half to two-thirds of the basal area of these stands consisted of sugar maple. An exception was a higher proportion of cavities in beech in two unmanaged stands.

In the oak–hickory managed stand the number of cavities was also related to the basal area of the tree species. In this stand the dominant species was black oak. In the old growth stand, however, two-thirds of the cavities were in the old-growth white oak which comprised 50 percent of the basal area.

Cavities at the Base of Tree Boles

Entrance sizes and inner horizontal development of tree base cavities were similar to those of cavities above the base; however, the vertical extent of tree base cavities was greater than that of cavities in the upper boles. In the different stands, from 30 to 50 percent of the tree base cavities were 2 ft. or more in vertical extent.

These cavities were generally located in the enlarged bases of large trees, often at ground level. Occasionally cavities were formed by separations between swollen portions of the tree base and sometimes were a result of decay and animal excavation of rotted material; entrances were often enlarged by removal of soil below the tree base.

Tree base cavities occurred mainly in the larger trees and predominantly in beech and sugar maple. They were uncommon in the oak–hickory type; only one was found in the managed stand.

Animal Use of Cavities and Burrows

Tree bole cavities above the base.—A cavity was considered used only when an animal was actually observed or photographed in it or when various signs indicated fairly recent and constant activity. Evaluations of this kind are subject to error; however, I believe the tendency was to underestimate rather than to overestimate the amount of use.

As indicated in Table 3, a variety of animals used the cavities and burrows. In the beech–maple stands, fox squirrels and birds were the most common users of tree cavities; however, the proportion of cavities used was low. Thirty percent of the cavities were large enough to be used by fox squirrels for refuge or nesting; according to field observations only 5.6 percent were actually used. In the oak–hickory stands fox squirrels utilized cavities more than other species; here also only a small proportion of cavities usable on the basis of dimensions was actually used.

Cavities used by fox squirrels had fairly uniform dimensions. Entrance holes were generally about 3½ in. in diameter; diameters of the horizontal cross section varied from 6 to 10 in., and the vertical extent from 20 to 60 in. The cavities commonly

TABLE 3.—PROPORTION OF CAVITIES AND BURROWS USED BY ANIMAL SPECIES

Animal Species	Type of Cover Used	Proportion of Cavities and Burrows Used Estimated from Signs or Observations of Animals (percent)	
		Beech–maple	Oak–hickory
Starling (*Sturnus vulgaris*)	Tree bole	3.2	0
Other birds—mainly white-breasted nuthatch (*Sitta carolinensis*) and tufted titmouse (*Parus bicolor*)	Tree bole	4.7	3.1
Red squirrel (*Tamiasciurus hudsonicus*)	Tree bole	0	1.5
Bat	Tree bole	0.1	0
Bees and wasps	Tree bole	0.3	3.1
Fox squirrel (*Sciurus niger*)	Tree bole, tree base	5.6	9.6
Raccoon (*Procyon lotor*)	Tree bole, tree base, burrow, log	3.0	0
White-footed mouse (*Peromyscus leucopus*)	Tree base, burrow, log	4.9	0
Red fox (*Vulpes fulva*)	Burrow	18.0	0
Eastern cottontail (*Sylvilagus floridanus*)	Burrow	7.4	0
Badger (*Taxidea taxus*)	Burrow	3.7	0
Unknown	Tree bole, tree base, burrow, log	8.5	16.0
None	Tree bole, tree base, burrow, log	73.0	68.0

occurred from 20 to 40 ft. from the ground, and were mainly in sugar maple, beech, and oak.

Starlings, nuthatches, and titmice nested in some of the cavities. Starlings were most numerous in the unmanaged stands where there was the greatest number of cavities. Cavities of various dimensions were selected for nests. Although entrance diameters were as large as 6 to 10 in., most were about 3 in. Horizontal cross-section diameters ranged from 4 to 9 in. and the vertical extent varied from 6 to 20 in. Often these cavities were large enough for fox squirrels and may have been used by them at other seasons of the year.

Raccoons were trapped in all of the stands; however, cavities of adequate size for them occurred only in the beech–maple type. In the unmanaged stands 2 to 3 percent of the tree bole cavities were large enough to be used by raccoons for refuge or nesting; on a density basis there was one cavity per 1 to 2 a. Judging from signs and actual observations of the animals, I estimated that approximately half of these were used. Most of the cavities occurred in sugar maple, beech, and basswood, generally in trees over 20 in. d.b.h.

When the cavities were being measured and observed in the field, the tallyman estimated the use value of the cavity from the ground for fox squirrels or raccoons. During the analysis of the data, this tally was correlated with indications of animal use based on the close observation of each cavity. An interesting result was that from 57 to 68 percent of the cavities which appeared to have possible use when viewed from the ground in the beech–maple stands were apparently unused. Some were unused because of the small size of the interior or be-

cause of poor drainage. Others which appeared to be good for refuge or nesting were also unused for reasons unknown.

Cavities at the bases of tree boles.—Although cavities in tree bases are available to animals which ordinarily remain on or near the ground, they may also be used by animals associated with higher cover in the tree boles. Apparently the large tree base cavities are generally used as temporary refuges by the larger mammals. Many cavities at this level would probably be too damp or too easily available to terrestrial predators for permanent use by squirrels and raccoons. Mice made use of some small cavities for refuge and also for nesting.

Of the total number of basal bole cavities, approximately 30 percent were considered potentially usable by squirrels and 10 percent by raccoons on the basis of adequate size for these animals. According to signs and photographs, actual use occurred mainly in the cut unmanaged stand; here approximately 19 percent were used by squirrels and 7 percent by raccoons.

Burrows.—Burrows 4 in. in diameter and larger occurred in all of the stands except one, but were numerous only in the cut, unmanaged stand in loamy sand. Here, where the digging was easy and the drainage good, there were 3.9 burrows per acre (Table 1). In the cut, grazed stand there were about half this number in a few sandy spots.

The burrows were probably originally excavated either by woodchucks or foxes; however, raccoons often used the completed burrows as shown by automatic camera records (Fig. 2). Foxes were generally present in the cut, unmanaged stand and used some of the burrows (Table 3). One spring, during the time when observations were being made, litters were produced in three burrows within a stand of 4.8 a. Camera records also indicated occasional use of the burrows by cottontails and badgers.

The use of burrows varied considerably with seasons and by years. For 2 years most of the numerous burrows in the cut, managed stand showed signs of heavy use; during the next 2 years, however, many were unused and were filled with leaves and soil. During this last year all the burrows were used again.

FIG. 2. Picture of raccoon entering a ground burrow taken with an automatic photographic unit.

Logs and leaf nests.—The few hollow logs which occurred in each of the stands were used occasionally by squirrels and raccoons, apparently for temporary refuge.

The leaf and twig nests were widely dispersed in each of the stands. Since only those in good repair were tallied, I assumed that they were used at the time of observation or had been in use recently.

DISCUSSION

The significance of the number of cavities and burrows in relation to animal numbers is difficult to determine because various factors affect not only the size of animal populations and their seasonal distribution but also the interpretation of observations and the efficiency of trapping. Some relationships, however, may be indicated from the data available. The largest numbers of hole-nesting birds occurred in the stands having the most cavities. Also, raccoons were most numerous in stands having the largest number of suitable cavities. On the other hand, the number of fox squirrels was high in the managed beech–maple stand with relatively few cavities. In the oak–hickory stands where there were very few cavities, fox squirrel numbers were also moderately high. Leaf nests were more common here than in all but one of the

other stands. In the stand where ground burrows were most numerous, numbers of foxes and raccoons were high.

SUMMARY

Measurements and observations of cavities in trees and logs, of ground burrows, and counts of leaf nests were made in four stands in the beech–maple type forest and in two stands in the oak–hickory type near East Lansing, Michigan.

A large proportion of the cavities originated from limb scars in the tree crowns; others were caused by rot, lightning scars, and frost cracks. The most cavities occurred in unmanaged stands of the beech–maple type. A large proportion of cavity entrances in boles above the bases were 2 to 4 in. in diameter. The size of cavities in tree boles as indicated by horizontal cross-section diameters was larger in the unmanaged than in the managed stands. The vertical extent of a cavity was generally proportional to the horizontal diameter. Cavities at bases of trees were common only in beech–maple stands, generally in enlarged bases of large trees.

Cavities in boles above the bases were most commonly used by fox squirrels and hole-nesting birds. Approximately half of the small number of large cavities were used by raccoons which were present in all beech–maple stands. Cavities in bases of trees were used primarily for temporary refuge by fox squirrels, raccoons, and mice. Burrows were most commonly used by red foxes and raccoons.

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ESTIMATING OPOSSUM POPULATIONS BY MARKING YOUNG

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This paper describes the application and results of a toe-clipping technique for marking young opossums (*Didelphis marsupialis*) taken while still in the pouch and ranging in age from 1 day to 3 months. The technique can be used efficiently in the field by one man.

Lay (1942) reported that nine young opossums of one litter were marked by toe-clipping when nearly ready to leave the mother, and Fitch and Sandidge (1953) reported 115 pouch young were individually marked by toe-clipping. The marking techniques used, however, were not described in detail.

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the Illinois Natural History Survey, cooperating.

DESCRIPTION OF AREA

The toe-clipping technique was applied during a comprehensive investigation of opossums and raccoons (*Procyon lotor*) in Allerton Park, Piatt County, Illinois. The study area is roughly rectangular, being approximately 2.5 mi. long and 1 mi. wide. It is divided by the Sangamon River, 775 a. lying generally to the south of the river and 1,031 a. to the north.

A dense stand of mature and over-mature timber covers about two-thirds of the area. The remaining third is in the early stages of woody succession although some fields are predominantly grassy with only a few woody invaders. A limited amount of bottomland hardwoods forest type (King and Winters, 1952:92) is present along the river, most of the area being in upland. The upland area is of the white oak forest type as described by King and Winters. The entire study area is surrounded by open fields of agricultural land, excepting for a minimum of woody cover at the river.

The soils of Piatt County are described by Smith, *et al.* (1930). The predominant soil type on the study area is Brown Mixed Loam found along the river bottom. The next two most common types are Brownish Yellow-gray Silt Loam and Reddish Brown Silt Loam on Drift, both found adjacent to the bottomland soils at different regions. Small amounts of three other soil types are also found within the area: Brown Silt Loam, Brown Silt Loam on Drift, and Eroded Gravelly Loam. The major soil types on the cropland surrounding the study area are Brown Silt Loam, Black Clay Loam on Drab Clay, and Brown Silt Loam on Drift, in that order.

This area is fairly typical of high-quality opossum habitat found along wooded sections of many of the larger streams in the prairie region of Illinois. It is not typical of Piatt County, which has only 2 percent of its area in forests, or of Illinois, which has 11 percent of its area in forests (King and Winters 1952:21).

METHODS AND EQUIPMENT

This report is based on live-trapping operations during 1957, 1958, and 1959. Trapping was begun each year in March or April and was continued as weather permitted until October 31. The hunting season for raccoons and opossums opened on November 1 in 1957 and 1958, and on October 15 in 1959.

Box traps of the type described by Butterfield (1954) were used, but some important modifications were made. Eighteen-gauge sheet steel was used for the drop doors instead of wood, and the parts of the grooved uprights exposed to the inside of the trap when the door was down were covered with 26-gauge sheet metal to prevent raccoons from chewing the wood and escaping.

The various baits used included dried corn (both shelled and on the cob), canned sardines, fresh fish, commercial raccoon lures, Purina Dog Checkers, and Purina Fox Checkers (Ralston Purina Co., St. Louis, Mo.). The last product was the most satisfactory.

Trapped opossums were sexed and examined for previous markings. Females were checked for pouch young. Then ectoparasites were collected. Finally, after the opossum had been tagged in each ear, it was placed head first into a wire cone, and three wooden pins were pushed through the cone behind it. The animal was weighed and, if no pouch young were present, was released at the site of capture.

During the period of March–September of each year many young were found in pouches of female opossums. In 1957, females were examined to determine whether young were present in the pouch, but exact numbers and sex of pouch young were not determined. In 1958 and 1959, careful counts were made of numbers of young in the pouches, and, when possible, the sex was determined. Young males have a rudimentary scrotum, and, in females, the outline of the pouch is evident between 11 (McGrady, 1938) and 17 (Reynolds, 1942) days of age. Beginning on April 10, 1958,

FIG. 1. Marking a litter of nine young opossums. Note the toe already clipped on the foot at top left center of the picture.

all but the very small young were toe-clipped with small surgical scissors (Fig. 1).

A pattern of toe clipping described by Stuewer (1943) was used to identify members in each litter to determine their dispersion and mortality. No attempt was made to assign an individual number to an animal on the basis of toes clipped; all members of each litter were marked the same way. All opossums which were live-trapped were examined to see if they had been toe-clipped. When a toe-clipped opossum was trapped after having left its mother it was ear-tagged.

No ear-tagged opossums lost toes by accident during this study. There was practically no steel trapping done on the area. Because toes clipped on young opossums were cut off flush with the foot and only one toe was removed per foot, it is believed that there was no confusion because of accidental loss of toes. Many opossums and raccoons are examined each year at fur buying establishments by the writer. Toes with only one or two joints missing are noted more often than entire toes missing, and two or more toes are absent from a foot more commonly than one.

Tags (Style 1005, No. 3, National Band and Tag Company, Newport, Kentucky) were placed as close to the head as practicable and away from the edge of the ear.

The female was placed with her back in the "V" of a shortened version of a "dog board" with her head and feet tied down to facilitate marking of her young. In this position the female was practically immobile, and the young could be counted, sexed, and toe-clipped. Care was taken not to detach the young from the nipples. To avoid counting the same animal more than once, the young were examined in sequence, and toes were clipped as soon as the sex was determined. The young were returned to the pouch so that none was left protruding and thus likely to become detached when the female was released.

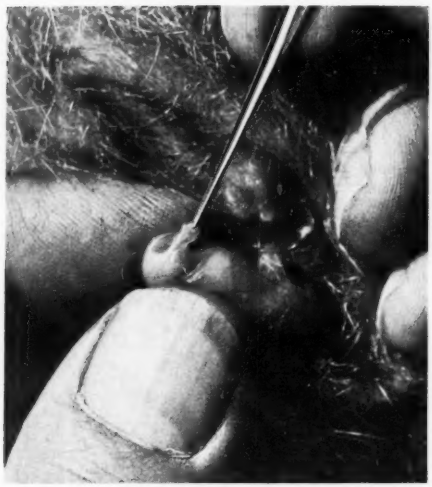

FIG. 2. Even with small scissors it was impossible to clip the hind toes of opossums less than about 10 days old. Fine-tipped forceps were used to mark animals of this size.

In 1958, pouch young less than about 10 days old were not toe-clipped because their toes, especially those of the undeveloped hind limbs, were too small for clipping, even with fine scissors. In 1959, however, attempts to toe-clip all pouch young with a pair of very fine-tipped forceps probably were successful (Fig. 2). The small, sharp points of the forceps were held parallel to the length of the foot until the toe was grasped; then it was pinched off. If the forceps were held crosswise it was almost impossible to catch only one toe on the hind foot unless it was an outside toe. Extreme care was necessary, but from observations on young opossums that were checked when their mothers were retrapped or when the young themselves were live-trapped, it appeared that this method was successful even on hind limbs of opossums estimated to be only 1 day old.

All population estimates are given as of July 1. During the 3 years covered, this date was always near the middle of the trapping period and also was near the date on which half of the initial captures had been made for the season. Taking into consideration both the middle of the trapping period and the date at which half the initial captures had been made, I found that the average dates for the three seasons were: June 30, 1957; July 11, 1958; and July 24, 1959.

RESULTS AND DISCUSSION

Toe-clipping of young in the pouch and retrapping them produce useful data. The "natal" ranges (the area used by the female while young are in her pouch) can be plotted on maps as can the range of marked individuals caught subsequently as free-living young animals or adults. Because several females may be caught repeatedly while carrying young, it is possible to calculate mortality in the pouch. Population densities, a comparison of sex ratios of pouch and free-living young, and average longevity can be estimated when enough opossums are marked while in the pouch and recaptured later.

Mortality of pouch young.—During this study, 60 litters were examined, and 16 of them in the pouches of 14 females were re-examined and counted at intervals varying from 4 to 62 days after marking. The mean interval between the first and last examination was 34 days.

Initially there were 121 young in the 16 litters which were re-examined. By the time of the last examination, 8 of these litters had lost from 1 to 3 young each for a total loss of 14. The other eight litters, also examined repeatedly, lost no young. Handling the females and examining the young apparently had little effect on mortality of young. For example, in 1958, female No. 152 was examined three times while carrying a litter of 10 young without losing any of them. In 1959, she was examined three times and did not lose the one young comprising her first litter. She was handled 14 times while carrying her second litter in 1959. She lost 2 of 10 young of the second litter between July 2 and July 5, 1959. She was handled and examined eight more times before losing another young from the second litter between August 2 and August 7, 1959. She lost no further young while

being handled six more times. Female No. 217 had 10 tiny young in her pouch on June 24, 1959. On the basis of Petrides' (1949) measurements, it was estimated that they were born on June 11. All 10 young were still present on June 26 and July 6, but on July 11 only 9 were present. From July 11 through August 25, this female was live-trapped 17 times with no further loss of young. All her young were gone by August 28; this indicates that these young remained with the mother for approximately 75 days. In the litters which suffered loss there was no apparent correlation between the number of times handled and the number of young lost.

Hamilton (1958) reported that in New York the number of pouch young apparently does not decrease noticeably as they develop, an observation that indicates no substantial mortality during the pouch stage. However, he pointed out that after 75 days the numbers in the pouch decreased because the young leave the female at intervals. In Kansas a fairly high rate of mortality was believed normal in small, dependent young, and further mortality probably resulted from examining and handling the young and their mothers (Fitch and Sandidge, 1953). Of 208 young recorded by them, 47 were missing at subsequent recaptures before they were old enough to leave the mother. The Kansas workers believed that the actual losses were much higher because records for each female covered only part of the period in which young were carried in the pouch.

The 12 percent mortality found during the present study was more than that indicated by Hamilton's (1958) data, but considerably less than the 23 percent reported by Fitch and Sandidge (1953).

Sex ratios of pouch young and live-trapped young.—Of 216 pouch young sexed during 1958 and 1959, 50 percent were females (Table 1). This is practically the same sex ratio as in all young-of-the-year animals live-trapped during the same period. There were slight annual differences in sex ratios, but when the data for the 3 years were combined there were 146 young and 49 percent of them were females. Thus, it appears that sex ratios of young opossums in the pouch were about 50:50 on the study area, that the mortality rates of both sexes in young opossums up to the time they were retrapped were similar, and that young-of-the-year male and female opossums are equally vulnerable to live-trapping. Petrides (1949) examined 5 litters in the pouch and found 21 males and 27 females or 56 percent females.

Table 1.—Number and Sex of Young Opossums Toe-clipped While in the Pouch, and Number and Sex of Toe-clipped and Unmarked Young-of-the-year Opossums That Were Live-Trapped

	1957[1]	1958	1959	1958–59 Combined
NUMBER OF POUCH YOUNG TOE-CLIPPED				
Males	0	42	65	107
Females	0	39	70	109
Percent Females	–	48	52	50
NUMBER OF YOUNG LIVE-TRAPPED				
Toe-clipped				
Males	0	8	10	18
Females	0	4	11	15
Percent Females	–	33	52	46
Not Previously Marked				
Males	41	18	38	56
Females	24	24	33	57
Percent Females	37	57	46	50
Total				
Males	41	26	48	74
Females	24	28	44	72
Percent Females	37	52	48	49

[1] Pouch young were not sexed or toe-clipped in 1957.

Fitch and Sandidge (1953) recaptured 15 of 115 young marked while in the pouch and reported that all but 2 were females. From this they concluded that young males must tend to wander much more widely than young females after leaving the mother and thus settle in new areas where they are not recaptured. Our data indicate that this is not true for this area in Illinois, especially during the year in which the young are born. Sandidge (1953) also reported that examination of 16 pouch young and 56 opossums caught in live traps yielded an equal sex ratio.

Production of young and population density.—With a known number of young toe-

TABLE 2.—POPULATION ESTIMATES AS OF JULY 1 FOR ALLERTON PARK, ILLINOIS, BASED ON DATA OBTAINED FROM YOUNG MARKED WHILE IN THE POUCH

	1957	1958	1959
No. of pouch young toe-clipped	0	122	156
No. of young live-trapped after leaving the female	66	54	92
No. of young marked in the pouch which were later live-trapped	–	12	21
Estimated no. of young on the area	–	549	527
Estimated no. of adult[1] opossums on the area	–	178	160
Population estimate	–	727	687
Estimated population per sq. mi.	–	222	244

[1] Based on number of young per adult female and assuming equal numbers of adult males and females.

clipped in the pouch and a ratio of toe-clipped and unmarked young opossums live-trapped on the study area, it is possible to estimate the total production of young on the area. In 1958, 122 pouch young were toe-clipped. After these and other young opossums left their mothers, 54 were live-trapped on the study area, 12 of which had been toe-clipped. Thus, 122:*X*::12:54 = an estimate of 549 young opossums which were produced on the area in 1958 (Table 2). In 1959, 156 young were toe-clipped while in the pouch. Ninety-two young were live-trapped on the study area, and 21 of these had been toe-clipped. Thus, 156:*X*:: 21:92 = 527 young opossums produced on the area in 1959 (Table 2).

Because we know the average litter size and the number of adult females without young, we can estimate the adult female population. During 1958, the 26 adult female opossums which were live-trapped produced a known total of 160 opossums (Table 4), or 6.2 young per female, including 6 females with no young. To produce 549 young opossums, 89 adult females must have been present on the study area. If we assume that 89 adult females and the same number of adult males were present on the area, there were 178 adults and, in addition, 549 young, or 727 opossums in 1958 after second litters were born. This assumes that there was no juvenile mortality up to that time. Thus, in 1958, we arrive at an estimate of 222 opossums (Table 2) per sq. mi., based on data from young marked in the pouch and caught later, which may be compared to the estimate of 234 per sq. mi. based solely on the live-trapping returns.

During 1959, the 26 adult female opossums which were live-trapped, including 6 with no young, produced a known total of 171 opossums, or 6.6 young per adult female (Table 4). On the basis of the same assumptions and methods of calculations used in 1958, 687 opossums were estimated for 1959 (Table 2), or 244 opossums per sq. mi. as compared to the estimate of 222 for 1958.

Petrides (1949) summarized sex-ratio data on opossums from studies in Texas, Missouri, and Ohio based on live-trapping, hunter reports, and examination of pelts. Males were more numerous in all but one case cited, ranging from 58 to 54 percent. Sex ratios obtained throughout the year by live-trapping in Ohio were an exception; there males comprised only 42 percent of the animals examined. Petrides points out that the high ratios of males in Texas and Missouri may not mean more males in the wild inasmuch as males are more prone to move about in cold weather than are females. In the present study, 124 adult opossums were live-trapped of which 53 (43 percent) were males. Our live-trapping was done only in the spring, summer and fall months. It appeared from our trapping records that adult females were easier to trap than adult males because a larger proportion of females were retrapped. In any case, it seems unlikely that an important error would be introduced by assuming that there were equal numbers of adult males and adult females on the area.

Population estimates can be based on the ratio of marked to unmarked animals captured on the area the year following initial trapping. Data in Table 3, based on this

TABLE 3.—POPULATION ESTIMATES AS OF JULY 1 FOR ALLERTON PARK, ILLINOIS, BASED ON RATIO OF MARKED TO UNMARKED OPOSSUMS RETRAPPED THE YEAR FOLLOWING INITIAL CAPTURE

	1957[1]	1958	1959
Number of opossums live-trapped and marked	94	107	128
Adults live-trapped the following year			
Previously marked	7	6	–
Unmarked	53	31	–
Population estimate based on live-trapping returns	806	660	–
Estimated population per sq. mi	289	234	–
Number of opposums live-trapped per sq. mi.	78	38	45

[1] Trapped on the 775 a. south of the river in 1957.

method of estimating, indicate a population of 806 opossums on July 1 in 1957 and 660 in 1958. This gives an estimate of 289 opossums per sq. mi. for 1957 and 234 per sq. mi. in 1958. Of course, these estimates assume that egress and ingress on the area are negligible. This may or may not be a valid assumption, but this study area is woodland almost completely surrounded by intensively farmed cropland. Opossums were not studied on the surrounding croplands but the roads around the area were checked for dead opossums; and farmers, hunters, and trappers on the surrounding areas were contacted for information regarding tagged opossums. These observations indicate that there was very little movement of marked animals off the area. Lack of suitable habitat for any large number of opossums on the surrounding cropland makes it unlikely that there was any substantial ingress of opossums. Reynolds (1945) suggested that most opossums on the area he studied in Missouri were nomadic and that few of them established a fixed home range in fall, winter, or spring. He did not study summer ranges. There is considerable evidence from the present study that many opossums have well-established home ranges that are relatively small, and that at least some animals maintain the same home range for several months. No opossums in central Illinois were live-trapped more than 15 months after their first capture, and only 6 of 329 animals retrapped were caught 11 or more months after their initial capture; these facts indicate that few opossums in this area live beyond the summer following their birth.

Our population estimates are much higher than most that have been reported for opossums. Hamilton (1958) reported that trappers took 51 opossums on approximately 2,000 a. of the Montezuma National Wildlife Refuge in New York. He states, "probably one opossum to 30 acres of this marsh is a reasonable estimate of the population. This suggests about 20 or more opossums to the square mile." Lay (1942) estimated the opossum population, excluding young in pouches, on his 86-a. Texas area at probably more than 1 to 4 a. (160 per sq. mi.). His estimates were "deduced" from minimum populations as determined by live-trapping. Fitch and Sandidge (1953) reported that for their 590-a. Kansas area the opossum population in early autumn was about 1 per 20 a. (32 per sq. mi.). They obtained their "crude census-figures" by using the Lincoln Index on the ratio of marked to unmarked opossums caught during sampling periods of three seasons with adjustments made for "probable" errors. We live-trapped from 38 to 78 different opossums per sq. mi. on our study area during the trapping period each year, including the young animals live-trapped separately from their mothers but not those counted in the pouches. No doubt some mortality of both young and adult animals occurred during our live-trapping period.

Using the adult female population estimate, we can calculate the percentage of adult females caught and compare it to the percentage of pouch young trapped later. Twenty-six adult females, or 29 percent of the estimated adult population, were live-trapped on the area in 1958 (Table 4). In 1958, only 10 percent of the young which were toe-clipped in the pouch were caught later the same year. Twenty-six different adult females, or 42 percent

TABLE 4.—NUMBER AND PERCENTAGE OF LIVE-TRAPPED ADULT FEMALE OPOSSUMS WITH POUCH YOUNG AND THE AVERAGE NUMBER OF YOUNG PER LITTER

Year	Females Live-trapped		Percent With Young	Number of Litters	Number of Young	Average Litter Size
	With Young	Without Young				
1957	15	2	88	15[1]	127	8.5
1958	20	6	77	21[2]	160	7.6
1959	20	6	77	22[3]	171	7.8

[1] Two females had 2 litters each; 2 females had pouch young, but the number was not determined.
[2] One female had 2 litters.
[3] Two females each had 2 litters.

of the estimated total adult female population, were also live-trapped on the area in 1959 (Table 4), and 14 percent of the young toe-clipped in the pouch were later live-trapped. These data may indicate that some young opossums move off the area soon after leaving the female, but a more likely explanation is that their mortality rate is much higher than that of the adult females.

Too few returns were received from hunters and trappers to estimate the population based on a comparison of marked and unmarked opossums killed.

SUMMARY

This paper describes a technique for marking young opossums captured while still in the pouch and some of the results obtained by application of the technique. Twelve percent of the young opossums in 16 litters examined in pouches were missing at subsequent examinations, ranging from 4 to 62 days later. It is not believed, however, that tagging and handling the females had any substantial effect on mortality of the young.

Sex ratios of young-of-the-year opossums were essentially 50:50, both in the 216 young examined in the pouch and in the 146 young animals live-trapped after leaving their mothers.

It is estimated that 549 young opossums were produced on the 1,806-a. area in 1958 and 687 in 1959. The population estimate for 1958, based on data from young marked in the pouch and caught later, was 222 opossums per sq. mi. The estimate made in a similar manner for 1959 was 244 per sq. mi. An estimate of 234 per sq. mi. was obtained for 1958 using live-trapping returns from the following year. It is estimated that 29 percent of the female population was marked in 1958 and 42 percent in 1959.

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MAGNITUDES OF REPRODUCTION IN COTTONTAIL RABBITS

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Many papers have been published concerning reproduction of the cottontail rabbit (*Sylvilagus floridanus*), but few of the studies have been quantitative. Studies by Elder and Finerty (1943), Ecke (1955), Schwartz (1942), Negus (1959), and Lord (1958) are some which present quantitative data.

This paper presents the results of a 3-year study designed to show a complete quantitative picture of reproduction in the cottontail rabbit in central Illinois.

David A. Casteel, Ronald F. Labisky and many others contributed much time and effort to collecting monthly samples of rabbits. Sarah Josephine Decker weighed the lenses of the rabbits' eyes. Thomas G. Scott, David E. Davis, Carl O. Mohr, Ralph E. Yeatter, and Barbara A. Chipman critically read the manuscript and offered advice.

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Methods

Rabbits were collected each month of the year for the years 1957, 1958, and 1959. Most samples were from Champaign, Piatt, McLean, and Ford Counties in central Illinois, although in 1957 some were taken in southern Illinois. Rabbits were taken at night (except in May, June, and July, when they were taken in the early morning) along country roads with the aid of a spotlight and shotgun. Rabbits were brought into the laboratory where the sex, weight, and tarsus length were recorded for each animal. Males were checked for the position, weight, and volume of the testis and for the presence or absence of sperm in the head of the epididymus. Females were checked for presence or absence of embryos, placental scars, and milk in the mammary glands. An eye was taken from each rabbit for estimation of age by the lens technique (Lord, 1959a).

Samples were taken monthly because the gestation period of the cottontail is about 1 month (Seton, 1929; Dice, 1929; Gerstell, 1937; Dalke, 1942; and Haugen, 1942) and they are known to copulate within a day or two after parturition. This means that samples taken monthly should reveal reproduction as it occurs during the breeding season.

The data were analyzed for the prevalence of pregnancy, average number of embryos per pregnant female, and the product of the two, which is the average number of young per female, otherwise known as the general fertility rate. This rate was used to compare the total production of young between months and years.

Pregnancy was determined macroscopically; therefore some pregnancies were probably missed which were so recent as to escape detection by this method. However, it seems reasonable to assume that the proportion of such pregnancies missed ought to be nearly constant for all months of the investigation.

In July of 1957, the first year of this study, two attempts to obtain rabbits on the roads at night failed. In the two subsequent years the July samples were obtained by collecting rabbits in the early morning (Lord, 1959b).

Because increasing light has been shown to be the stimulus for reproduction in the cottontail (Bissonnette and Csech, 1939), the total hours of sunshine recorded by the weather bureau were examined for possible agreement with prevalence of pregnancy for the 3 years of this study. Because of the lack of a sample for July 1957, and the fact that most of the year's production occurs in the 4-month period, March–June (88 per-

cent in 1957, 78 percent in 1958, and 70 percent in 1959), all comparisons of total hours of sunshine with prevalence of pregnancy are for this 4-month period only.

OBSERVATIONS AND DISCUSSION

Tables 1 and 2 list the data upon which the following observations and discussion are based. Fig. 1 illustrates the 3-year summary of cottontail reproduction.

TABLE 1.—PREVALENCE OF PREGNANCY (Pp) AND MEAN LITTER SIZE OF PREGNANT COTTONTAILS ($\bar{X}$) IN 1957, 1958, AND 1959

Month	Pp	$\bar{X}$	General Fertility Rate	Sample Size	
				Totals	♀♀
1957					
March	0.74	4.31	3.18	45	15
April	0.36	5.91	2.12	25	11
May	0.78	8.43	6.57	23	9
June	0.83	6.67	5.53	12	6
July	—	—	—	—	—
August	0.33	5.38	1.78	64	39
September	0.10	5.00	0.50	54	29
Total	3.14	35.70	19.68[1]	223	109
Annual mean	0.52	5.95	3.09	37	18
1958					
March	0.96	4.38	4.20	61	27
April	0.79	5.63	4.44	63	24
May	0.85	6.36	5.41	33	13
June	0.47	5.20	2.44	42	31
July	0.40	3.50	1.40	50	23
August	0.39	5.36	2.09	48	28
September	0.21	5.00	1.05	32	19
Total	4.07	35.43	21.03	329	165
Annual mean	0.58	5.06	2.93	47	24
1959					
March	0.97	4.61	4.47	56	29
April	1.00	6.08	6.08	54	27
May	0.83	6.33	5.25	54	24
June	0.64	4.50	2.88	36	14
July	0.60	5.07	3.04	83	45
August	0.59	5.57	3.29	57	32
September	0.33	5.00	1.65	49	24
Total	4.96	37.16	26.66	389	195
Annual mean	.70	5.31	3.81	56	28

[1] Total productivity in 1957 cannot be compared directly with that in 1958 and 1959 because of absence of a July sample. See text.

TABLE 2.—PREVALENCE OF PREGNANCY (Pp) AND MEAN LITTER SIZE OF PREGNANT COTTONTAILS ($\bar{X}$)—A 3-YEAR AVERAGE

Month	Pp	$\bar{X}$	General Fertility Rate	Sample Size	
				Totals	♀♀
March	0.92	4.45± .71	4.09	162	71
April	0.81	5.73± .85	4.64	142	62
May	0.83	6.68±1.07	5.54	110	46
June	0.53	5.11±1.63	2.71	90	51
July	0.55	4.79±1.15	2.63	133	68
August	0.47	5.47± .84	2.57	169	99
September	0.19	5.00± .68	0.95	135	72
Seasonal $\bar{X}$	0.60	5.31± .68	3.18		
Total				941	469

Because of the failure to obtain a sample in July of the first year, it was not possible to compare total production for this year with that of subsequent years. Total production for 1959 was 21 percent greater than that of 1958. This increase was caused both by an increased prevalenece of pregnancy (17 percent more) and an increased average litter size (4 percent more).

To examine the role of sunshine on rabbit production for the 3 years of the study, production for the first 4 months of the breeding seasons was used, as explained in the section on methods. In 1957, there were 894 hours of sunshine in March, April, May, and June and the mean prevalence of pregnancy for these months was 0.68. For the same 4 months in 1958 there were 1,006 hours of sunshine, and the mean prevalence of pregnancy was 0.77. In 1959, there were 1,021 hours of sunshine for the same period, and the mean prevalence of pregnancy was 0.86. Thus, for the 3 years of the study an increasing amount of sunshine was accompanied by a corresponding increasing prevalence of pregnancy. In addition, in April of 1957, there was a decrease from the previous month in the prevalence of pregnancy, and a corresponding decrease in the hours of sunshine for this same month. In June and July of 1958, there was another unusual decrease in the hours of sunshine and a corresponding decrease (compared with other years) in the prevalence of pregnancy for these 2 months (Fig. 2).

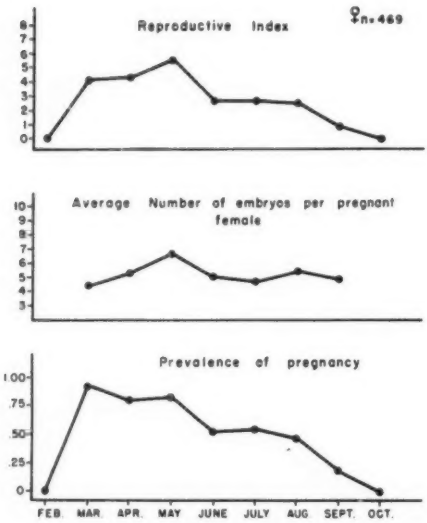
Reproductive Index
♀n=469
Average Number of embryos per pregnant female
Prevalence of pregnancy
FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT.

FIG. 1. A 3-year average of cottontail reproduction in central Illinois.

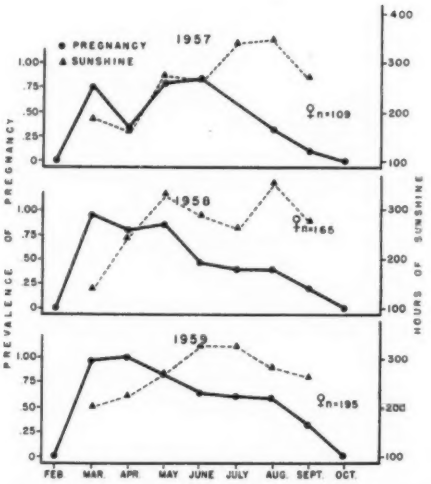

FIG. 2. A comparison of prevalence of pregnancy with hours of sunshine during the breeding season of cottontail rabbits.

Ordinarily the amount of light on cloudy days is considered adequate to stimulate reproduction; yet the data contained here appear to indicate that quantitative differences in light may possibly produce quantitative differences in the reproductive response of a population. The correlation of prevalence of pregnancy with hours of sunshine was not statistically significant, but this may be a result of small sample size. The mechanism for this apparent cause and effect relationship, if it is real, remains to be discovered.

Bruna (1951) pointed out that the average litter size of cottontail rabbits in Kentucky appeared to be lower (4.4) than those reported by Dalke (1942) in Connecticut (5.0–5.5), Haugen (1942) in southern Michigan (5.4), and Trippensee (1936) in southern Michigan (5.04). He did not mention that Schwartz (1942) also found a smaller average litter size in Missouri (4.4). All other recorded average litter sizes for *Sylvilagus floridanus* are from latitudes more northerly than those of Missouri and Kentucky and show larger litter sizes: Allen (1938) in southern Michigan (5.1); Beule (1940) in Pennsylvania (5.42); Gerstell (1937) in Pennsylvania (5.0); Hendrickson (1943) in Iowa (5.7); Ecke (1955) in Illinois (5.6); Negus (1959) in Ohio (5.5); and Lord (1958) in Illinois (5.52±3.11). Only Hamilton (1940) reports an exception to this rule with an average litter size of 4.5 for 22 pregnant female cottontails collected in New York.

Both Missouri and Kentucky are between latitudes 37 and 38 degrees north. A portion of southern Illinois is also in this same zone. During 1956, Glen C. Sanderson collected rabbits in both southern and central Illinois, and in 1957 the author collected rabbits from the same two areas. An examination of the data from these rabbits revealed 34 adult pregnant female rabbits from southern Illinois had an average litter size of 4.77±1.13 with a standard error of 0.19. Another sample of 29 adult pregnant female rabbits from central Illinois (roughly 200 mi. north) had an average litter size of 6.17±1.98 with a standard error of 0.37. The means are statistically different at the 1 percent level with a t value of 3.54.

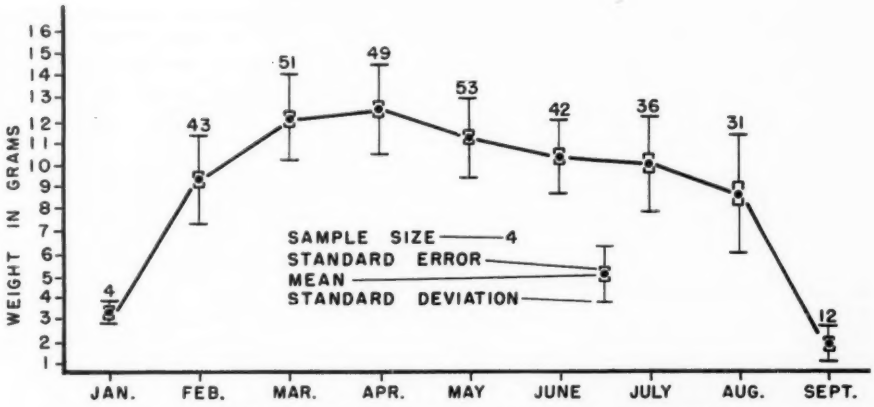

FIG. 3. Monthly variation in testes weights (one testis from each rabbit).

The rather high mean litter size among the females collected in 1956 and 1957 in central Illinois prompted a test for the significance of the difference between the southern Illinois sample and a 3-year sample taken from central Illinois during 1957, 1958, and 1959. Here a sample of 175 adult pregnant female rabbits showed an average litter size of 5.56±0.90. Again the *t* value (4.49) indicated a significant difference between the average litter size of cottontails from southern Illinois compared with that of cottontails from central Illinois.

Resorption of embryos was quite low during the 3 years of the study. In 1957, no resorbing embryos were found; in 1958, 8 percent of the females had an embryo in resorption and in 1959, 5 percent had an embryo in resorption. Except for one female in 1958 which had two resorbing embryos, all other cases of resorption involved only one embryo out of the litter. No cases of resorption of the total litter were found.

The weight of 1 testis from each of 321 adult male rabbits was taken and the means were plotted on Fig. 3. These weights indicate that for the male the breeding season starts in February and ends in August. This span is in agreement with the data taken from females when it is realized that copulation must occur the month before parturition. Elder and Finerty (1943) show a similar curve of testis growth and regression for rabbits in Wisconsin. Their curve indicates that although the breeding season is similar for that state, testes weights of Wisconsin rabbits appear to be considerably larger during the breeding season than do weights of testes from Illinois rabbits. Brambell (1944), in an exhaustive treatise on the reproduction of the wild rabbit (*Oryctolagus cuniculus*) in England, shows a curve of testis growth which indicates a breeding season of only 4 months' duration. The testes weights of this rabbit, body weights of which average half again as much as the cottontail, are only one third those of the cottontail during the peak months for both species.

Because the eyes of most rabbits collected during this study were in suitable condition for removal of the lens, the age of most of the rabbits could be estimated by the lens technique. The data in Table 3 show that the average litter size increases with age, at least up to 3 years. The prevalence of pregnancy is lowest among juveniles, highest in the 1-year age class and successively lower for the 2- and 3-year age classes. The general fertility rate is similar to the prevalence of pregnancy with respect to age.

The ages of 21 pregnant juvenile females were determined by the lens technique. Of these females, five were 2 to 3 months old,

TABLE 3.—AGE-SPECIFIC BIRTH RATES OF FEMALE COTTONTAILS

Age Class	Avg. No. of Embryos	Prevalence of Pregnancy	General Fertility Rate	Number of Rabbits
Juvenile[1]	4.72± .79	0.31	1.46	20
1 year	5.44± .80	0.77	4.20	130
2 years	5.87±1.20	0.70	4.11	31
3 years	6.00±1.12	0.68	4.08	13

[1] Female rabbits captured during the season of their birth.

six were 3 to 4 months old, nine were 4 to 5 months old, and one was 5 to 6 months old.

In an earlier paper (Lord, 1958) the author concluded that 24–27 percent of the annual crop of cottontails was contributed by juvenile breeding. More recently, a survivorship curve showing age-specific probability of dying among cottontails has been constructed from monthly samples collected the year around (Lord, 1961). This survivorship curve permits a more refined analysis of juvenile breeding data. When the survivorship data were applied to the 1957 data previously reported, the resultant figure showed that juvenile breeding contributed more than 23 percent of the annual crop. The minimum nature of the final figure again is because of the failure to obtain a sample in July of 1957 (Table 4). The same analysis was repeated with data for 1958 and 1959 and shows that there was successively less contribution to the annual crop by juvenile breeding. This reduction in the amount of juvenile breeding occurred even though the July sample, missing in 1957, was included for 1958 and 1959; and, in 1959, juvenile breeding started in June, a month earlier than usual. This indicates an inverse relationship between the amount of adult breeding and juvenile breeding.

TABLE 4.—THE EXTENT OF BREEDING BY JUVENILE[1] FEMALE COTTONTAILS

	Percent of Breeding Females That Were Juvenile				Percent of Annual[2] Crop Contributed by Juvenile Breeding
	June	July	Aug.	Sept.	
1957	0	—	55	76	22.93
1958	0	33	55	25	16.12
1959	33	19	16	63	12.29

[1] Female rabbits captured during the season of their birth.
[2] Method of calculation described in Lord (1958) includes female adult contribution of births from March, April, and May.

SUMMARY

Monthly samples of cottontail rabbits were collected during the breeding seasons of 1957, 1958, and 1959. The rabbits were analyzed for age, prevalence of pregnancy, average litter size, and general fertility rate.

There appeared to be a relation between prevalence of pregnancy and hours of sunshine.

An examination of data from other states indicates a lower average litter size in more southerly states. Analysis of data from southern Illinois showed a statistically significant lower average litter size than for rabbits collected from central Illinois.

The average litter size increased with age. Juvenile rabbits had the lowest prevalence of pregnancy and rabbits in the 1-year age class the highest, while those in the 2- and 3-year age classes showed successively lower prevalences of pregnancy.

The contribution of juvenile breeding to the annual crop was greatest during the first year of the study and became successively lower each of the following 2 years of the study. This indicated an inverse relationship between juvenile breeding and adult breeding which increased for the 3 years of the study.

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MORTALITY RATES OF COTTONTAIL RABBITS[1]

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Studies dealing with mortality rates of wild mammals, including cottontail rabbits (*Sylvilagus floridanus*), are usually based on samples of animals taken from the living population. Individuals in the samples are classified according to age, and the relative survivorship of age classes is compared. Hale (1949) refined the epiphyseal cartilage test developed by Thomsen and Mortensen (1946), making it possible to identify young-of-the-year up to January. This made possible the analysis of cottontail populations by two age classes and calculation of mortality rates (Lord, 1958).

The present study is based on samples of cottontail rabbits taken over a 3½-year period and classified into monthly age categories by the lens technique (Lord, 1959).

David A. Casteel, Ronald F. Labisky and many others contributed much time and effort to the collecting of monthly samples of rabbits. Sarah Josephine Decker weighed the lenses of the rabbits' eyes. Thomas G. Scott, Carl O. Mohr, and Barbara A. Chipman critically read the manuscript and offered advice. I am grateful to the division of law enforcement of the Illinois Department of Conservation, and to the Sheriffs of Champaign, Piatt, Ford, and McLean Counties for their cooperation in this project.

METHODS

Samples of rabbits, taken mostly from Champaign, Piatt, McLean, and Ford Coun-

[1] A contribution from Illinois Federal Aid Project No. 42-R, the Illinois Department of Conservation, the U. S. Bureau of Sport Fisheries and Wildlife, and the Illinois Natural History Survey, cooperating.

[2] Employed by the Illinois Department of Conservation under terms of the Federal Aid in Wildlife Restoration Act and assigned to the Illinois Natural History Survey for administrative and technical supervision.

TABLE 1.—NUMBER OF COTTONTAIL RABBITS TAKEN EACH MONTH, NOTED BY MONTHLY AGE CLASS (1956–59)

Age in Months	Months												Total Rabbits
	January	February	March	April	May	June	July	August	September	October	November	December	
1							4	5			2		11
2						4	16	10	5	5	19	3	62
3	4	6					9	23	11	17	29	17	116
4	6	8					3	13	20	22	34	21	127
5	9	6						2	9	25	23	27	101
6	14	3	8	3				1		24	26	26	105
7	19	9	19	13	8					9	22	31	130
8	8	2	15	8	5	1	1			3	5	17	65
9	5	2	15	17	14	4	2		1		3	10	73
10	4	3	16	15	13	7	7	1	3		1	3	73
11	3	4	10	22	16	4	10	14	4		1	2	90
12	1	1	5	10	7	6	11	13	4	3	3		64
13	1	1	4	7	8	7	5	7	2				42
14				1	4	3	6	3		5	1	1	24
15				4	1	3	3	10	1	4		2	28
16	5			1	3	2		1	1			1	14
17				1	2		2			3	1	1	10
18	1		2	2	3		4	1	2	5		1	21
19		1	1	1	1		6	3			1	1	15
20	2	3		1		1	2	2	2	4	1	3	21
21			1		2		1	2				2	8
22	1	1	2	1			2	4	2			4	17
23	2		1	2	1	2	1	2		3			14
24			1	1	1					3			6
25			1			1	1						3
26	1		2	1		1	3	1			2	2	13
27				2	1			1			1		5
28					1		1		3		1		6
29				3	1	1	4	1				4	14
30	1			1				1					3
31		1				1					2		4
32			1	1	1			1			1		5
33			1		1			3			2		7
34							1						1
35													
36													
37													
38					1		1						2
Total	87	51	105	118	95	48	106	125	70	135	181	179	1300

ties in central Illinois, were collected each month from July 1956 to December 1959. In 1956 and 1957, some samples were taken in the southern part of the State. The rabbits were taken at night (except in May, June, and July, when they were taken in the early morning) along country roads with the aid of a spotlight and a shotgun. Rabbits were brought into the laboratory for examination when routine biological information was gathered and an eye was taken from each rabbit. Each rabbit was assigned to a monthly age category according to the dry weight of its lens.

OBSERVATIONS AND DISCUSSION

Eighty-six rabbits were collected from July to December of 1956. In 1957, 262 rabbits were collected. In 1958, 469 rab-

TABLE 2.—AGE DISTRIBUTION OF RABBITS CAUGHT AND THEIR CALCULATED PROBABILITY OF DYING

FIELD DATA		CALCULATED FROM FIELD DATA			
Age in Months	No. of Rabbits Dying in Month	No. of Rabbits at Start of Month	Survivors as Percent of Total	Number of Deaths per 1000 Alive at Beginning of Month	Probability of Dying During the Month
0–1	0	—	—	—	—
1–2	11	1300	100.00	8.5	.01
2–3	62	1289	99.15	48.0	.05
3–4	116	1227	94.39	94.6	.10
4–5	127	1111	85.46	114.3	.11
5–6	101	984	75.69	102.7	.10
6–7	105	883	67.92	118.8	.12
7–8	130	778	59.85	167.1	.17
8–9	65	648	49.85	100.3	.10
9–10	73	583	44.85	125.3	.13
10–11	73	510	39.23	143.0	.14
11–12	90	437	33.62	206.1	.21
12–13	64	347	26.69	184.3	.18
13–14	42	283	21.77	148.4	.15
14–15	24	241	18.54	99.8	.10
15–16	28	217	16.69	128.8	.13
16–17	14	189	14.54	74.3	.07
17–18	10	175	13.46	57.2	.06
18–19	21	165	12.69	126.9	.13
19–20	15	144	11.08	104.7	.11
20–21	21	129	9.92	162.3	.16
21–22	8	108	8.31	74.6	.08
22–23	17	100	7.69	169.1	.17
23–24	14	83	6.39	169.0	.17
24–25	6	69	5.31	86.6	.08
25–26	3	63	4.85	47.4	.05
26–27	13	60	4.62	217.0	.22
27–28	5	47	3.62	108.0	.11
28–29	6	42	3.23	142.0	.14
29–30	14	36	2.77	390.0	.39
30–31	3	22	1.69	138.0	.14
31–32	4	19	1.46	212.0	.21
32–33	5	15	1.15	330.0	.33
33–34	7	10	0.77	701.0	.70
34–35	1	3	0.23	348.0	.35
35–36	—	2	0.15	—	—
36–37	—	2	0.15	—	—
37–38	—	2	0.15	—	—
38–39	2	2	0.15	1000.0	1.00
39–40	0	0	0.0	—	—

bits were collected and in 1959, 689 rabbits were collected, making a total of 1,506 rabbits. Not all rabbits were in condition for removal of eyes and many lenses were discarded because of deterioration or damage. The total number of rabbits whose ages were determined by the lens technique was 1,300.

Tables 1 and 2 list the data upon which the following observations and discussion are based. Fig. 1 illustrates the relative abundance of rabbits of different ages throughout the year. This figure also shows increase of age and diminution of numbers in generations of rabbits with the progression of time. It is apparent that exceedingly few rabbits live to be 3 years old even though their potential life span is probably about 10 years (Lord, in press).

Fig. 2 is the survivorship curve constructed from column 4 of Table 2. This curve appeared to be a logarithmic one and,

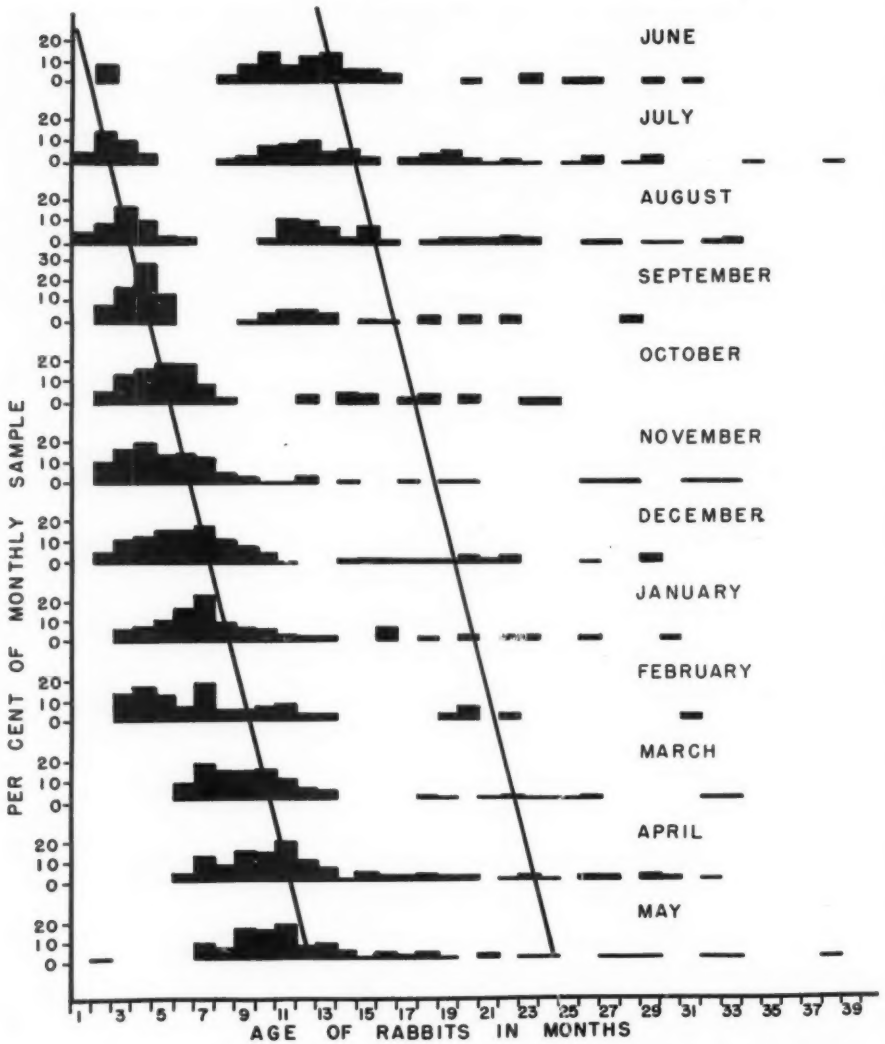

FIG. 1.—Monthly changes in the age composition of a cottontail population in east-central Illinois.

when tested, proved to plot a straight line (regression of −0.059) from the 4th to the 29th month of life. After the 29th month, the rate of survival drops off more rapidly than the logarithmic plot predicts. This digression may be because of the small sample of these very old rabbits, error in the lens technique, or a real biological digression.

Prior to the fourth month of life, there are fewer rabbits in the sample than the plot of the logarithmic curve predicts. The

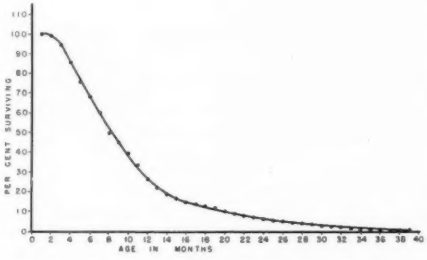

FIG. 2. Survivorship curve for cottontail rabbits.

sampling technique used probably does not secure rabbits younger than 4 months in numbers relative to their true proportion in the population. Nearly all of their first month of life is spent in or very close to the nest. It is likely that dispersal from the nest site takes place slowly at first and increases with advancing age. Therefore, one would not expect rabbits less than 4 months of age to appear on roads as frequently as older rabbits, and the data seem to support this assumption.

The major portion of the life table (Table 4) was constructed from data in Table 2. However, because of the indicated failure of the sampling technique to secure rabbits younger than 4 months in numbers relative to their true proportion in the population, the modified life table (Table 3) was constructed. The purpose of this table is to determine the probability of dying of rabbits in the 0- to 4-month age class for use in the cohort life table (Table 4).

By choosing an arbitrary population (of 1,000 rabbits) and assigning to it the age-specific mortality rates calculated in this study and the age-specific reproductive rates reported in another study (Lord, 1961), the total births and deaths of all rabbits were calculated for 1 year.

Then to determine the number of deaths of juveniles in the 0- to 4-months age class, the total number of deaths of juveniles 4 or more months old was added to the number of juvenile survivors at the end of the year, and the sum was subtracted from the total number of births for the year. The number of deaths of juveniles less than 4 months old divided by the total number of births equals the probability of dying for this age class.

In constructing the modified life table (Table 3), an arbitrary population of 1,000 was selected and assigned to the beginning of March-A. The mean adult probability of dying for March-A and each month thereafter was calculated from the data (Tables 1 and 2) and applied to the original 1,000 adults to determine figures for the first column of Table 3. The number

TABLE 3.—MODIFIED LIFE TABLE FOR COTTONTAIL RABBITS

Month	ALIVE AT BEGINNING OF MONTH			AT END OF MONTH						
				NO. OF BIRTHS			DEATHS			
	Adults	Juveniles 0–4	Juveniles 4+	by Adults	by Juveniles	Total Increment	Adult	Juvenile 0–4	Juvenile 4+	No. of Rabbits Alive
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
March–A	1000			2928		2928	154	545		3229
April	846	2383		1805		1805	138	881		4015
May	708	3307		1801		1801	115	1215		4486
June	593	3893		1004	104	1108	91	1423		4080
July	502	1024	2554	694	231	925	89	1050	278	3588
August	413	899	2276	564	335	899	76	881	244	3286
September	337	917	2032	248	278	526	54	643	236	2879
October	283	800	1796				36	436	219	2188
November	247	364	1577				50	265	197	1676
December	197	98	1380				36	98	186	1355
January	161		1194				20		160	1175
February	141		1034				23		152	1000
March–B	118		822							

TABLE 4.—LIFE TABLE FOR COTTONTAIL RABBITS

Age Interval in Months	Of 10,000 Rabbits in Uteri		Mortality Rate (Number Dying per 1,000 Alive at Beginning of Month)	Complete Expectation of Life (Average Number of Months of Life Remaining at Beginning of Month of Age)
	Number Alive at Beginning of Month of Age	Number Dying During Month of Age		
x	l_x	d_x	$1000q_x$	e_x
0–4	10,000	7440	744	6.5
4–5	2560	282	110	6.6
5–6	2278	228	100	6.5
6–7	2050	246	120	6.5
7–8	1804	307	170	6.4
8–9	1497	150	100	6.4
9–10	1347	175	130	6.3
10–11	1172	164	140	6.3
11–12	1008	212	210	6.3
12–13	796	143	180	6.3
13–14	653	98	150	6.2
14–15	555	55	100	6.0
15–16	500	65	130	5.8
16–17	435	31	70	5.6
17–18	404	24	60	5.3
18–19	380	49	130	5.0
19–20	331	36	110	4.9
20–21	295	47	160	4.6
21–22	248	20	80	4.4
22–23	228	39	170	4.2
23–24	189	32	170	4.0
24–25	157	13	80	3.7
25–26	144	7	50	3.4
26–27	137	30	220	3.1
27–28	107	12	110	2.9
28–29	95	13	140	2.6
29–30	82	32	390	2.4
30–31	50	7	140	2.3
31–32	43	9	210	2.1
32–33	34	11	330	1.9
33–34	23	16	700	1.9
34–35	7	3	350	2.3
35–36	4	—	—	2.0
36–37	4	—	—	1.5
37–38	4	—	—	1.0
38–39	4	4	1000	0.5

of births from adult females (column 4) was calculated from monthly age-specific reproductive rates (Lord, 1961) obtained from the same rabbits used for this study. The number of births to juvenile females (column 5) was calculated by determining from the data (Lord, 1961) the proportion of breeding females that were juveniles. This information makes it possible to calculate the number of breeding juvenile females in this hypothetical population and assign to them the mean litter size (4.72) for juveniles (Lord, 1961); and to determine the number of births from the juvenile segment of the population (column 5). In the above manner, total births (column 6) for this hypothetical population were calculated.

In determining the number of deaths of juveniles 4 or more months old (column 9), a stationary population was assumed. This meant that the population at the end of February or the beginning of March-B must equal 1,000 rabbits. Because the number

of adult survivors (118) had already been calculated for March-B (above), the 1,000 complement (882) of these survivors was the number of juveniles surviving that were born the previous summer.

The number of juvenile survivors in February was calculated as above, and the mean probability of dying for juveniles in February was calculated from the February sample (Tables 1 and 2). From this probability of dying, its complement, the probability of surviving, was calculated. Therefore, it was possible to calculate as follows the number of juveniles that died in February:

$$\text{Number of deaths of juveniles} = \frac{\text{Monthly probability of dying of juveniles} \times \text{Month's juvenile survivors}}{\text{Monthly probability of surviving of juveniles}}$$

The sum of February deaths and March-B survivors was the February survivors of juveniles more than 4 months of age (column 3). The calculations were then repeated as above for January and each month successively back to and including July, the first month to have 4-month-old juveniles (those born in March).

By subtracting from total births (9,992) the sum of juvenile survivors (882) and total deaths of juveniles 4 or more months old (1,672), the difference obtained (7,438) was the total number of deaths of juveniles from birth to 4 months of age. This represents a probability of dying for this age class of 0.744.

To complete the remainder of the modified life table, the number of deaths of juveniles in the 0- to 4-month age class (column 8) was calculated from the above estimation of the probability of dying. It should be mentioned, however, that because the data on reproduction was obtained from pregnant females this mortality rate includes intrauterine mortality. Prenatal mortality has been shown to be of importance in the European rabbit (*Oryctolagus*) by Brambell (1948) in England and Mykytowycz (1960) in Australia. Embryo resorption has been demonstrated to be of importance in the swamp rabbit (*Sylvilagus*) in Missouri (Conaway *et al.*, 1960). The latter two of the above references were concerned with unusually dense rabbit populations. The population density of cottontails in central Illinois agricultural fields, where most of the rabbits used in this investigation were obtained, is sparse, which could explain the difference in resorption noted in this study. The final column (10) of the table was calculated by subtracting deaths for any month from the sum of survivors and births for that month. This column provided data for construction of Fig. 3, which illustrates the annual cycle of abundance of the cottontail rabbit in east-central Illinois.

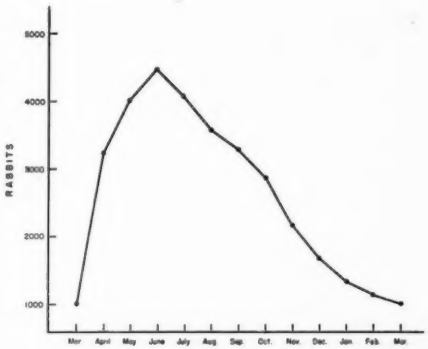

FIG. 3. Annual cycle of abundance of cottontails.

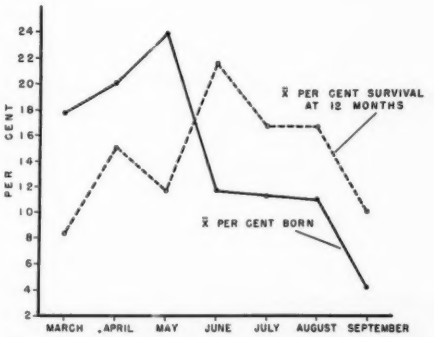

FIG. 4. Relative survival of cottontail rabbits to 12 months of age according to month of birth.

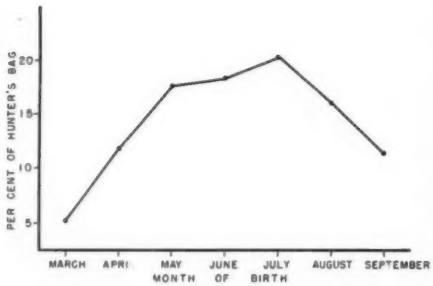

FIG. 5. Proportion of hunter's bag of cottontail rabbits according to month of birth.

Data presented elsewhere on reproduction (Lord, 1961) have made possible the calculation of the proportionate contribution of each breeding season month to the year's total production. Fig. 4 shows a plot of these data and compares it with a plot of the proportionate survival of rabbits born the previous year. It is apparent that rabbits born late in the breeding season had a much higher probability of surviving to 12 months of age than did rabbits born early in the season.

Age composition data collected during the months of the Illinois rabbit hunting season (December and January) showed the relative contribution of each month of the breeding season to the hunter's bag. These data were plotted in Fig. 5. Rabbits born in May, June, July, and August produced three-fourths of the hunter's bag.

SUMMARY

Monthly samples of cottontail rabbits were collected from July 1956 to December 1959. A total of 1,300 rabbits was obtained and each was assigned a monthly age by the lens technique.

Analysis of these data produced (1) a survivorship curve; (2) a cohort life table; and (3) a modified life table containing age-specific reproductive and mortality rates. From the modified life table, a curve showing the annual cyclic abundance of rabbits was constructed. Analysis of the relative survival of rabbits born during different months of the breeding season showed that rabbits born late in the season had a higher probability of surviving to 12 months of age than rabbits born early in the season.

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PARASITE TAGS FOR MARINE FISH

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Parasites of marine fishes as well as those of other animals often exhibit remarkable geographic variations in abundance. Differences may have environmental or physiological explanations, but regardless of their causes, such variations should prove useful to the study of fish populations and migrations. Parasites may serve as "natural tags" identifying fish from a particular area or of a particular age, and natural marks of this kind can be valuable supplements to tagging programs—in fact they may be a method of choice in studying stocks and movements of fish, particularly deepwater ones, that are difficult to tag.

Some information about populations and movements of marine fish has already been obtained through studies of parasite distribution and abundance. Parasite tags have been used with profit in studying the continental origin of high seas salmon stocks in the Pacific (Margolis, 1956). A parasitic copepod (*Sphyrion lumpi*) has provided information about the degree of discreteness of western North Atlantic redfish stocks (Templeman, 1950; Perlmutter, 1953). In European waters another parasitic copepod (*Lernaeocera branchialis*) has been used to identify inshore and offshore whiting and pollock (Sproston and Hartley, 1941). Lüling (1951) noted wide geographic variations in the abundance of larval nematodes (Anisakinae) in redfish from the Iceland area. Kabata (1957, 1959) found geographic variations in the abundance of parasitic copepods of the genera *Lernaeocera* and *Acanthochondria* on groundfish from the eastern North Atlantic.

During the past four years (1955–58), a study has been made of the distribution and abundance of parasites of sea herring (*Clupea harengus*) taken on the east coast of North America. Concurrent investigations of the life cycle and ecology of several of the parasites have also been carried out, and several reports on aspects of this work have been published (Sindermann, 1957a, 1957b). The present paper summarizes the information that parasites have provided about the movements or lack of movements of intraspecies groups of herring. Results may also be used as a baseline for the study of long-term changes in parasite abundance in this important marine fish.

The author wishes to acknowledge the assistance of Donald Mairs, Frank Perkins, Alva Farrin, and others of the staff of the Bureau of Commercial Fisheries Biological Laboratory, Boothbay Harbor, Maine, in collection and examination of samples. The hospitality and assistance of Alexandre Marcotte, Director, Marine Biological Station, Grande Rivière, Quebec, and Paul Montreuil, Director, Marine Biological Laboratory, Grindstone, Magdalen Islands, did much to make possible the Gulf of Saint Lawrence studies included here.

Methods

Herring are hosts to a large menagerie of parasites, some of which occur commonly, while others are rare, and some of which are relatively permanent while others are transient. Parasites reported in this paper include only those that have been found to persist in the host for a minimum of 1 year, to be easily visible, and to have a heterogeneous geographic distribution. Four parasites satisfied these requirements: *Ichthyosporidium hoferi*, a systemic fungus parasite that produces gross nodules on the heart and liver; larval cestodes of the order Trypanorhyncha, encysted in the mesenteries; larval nematodes of the subfamily Anisakinae, from the viscera; and a myxosporidian (*Kudoa clupeidae*) which produces cysts in the body muscles. A number of interesting organisms, including *Eimeria sardinae*, a sporozoan found in the testis, *Eimeria clupearum*, a sporozoan from

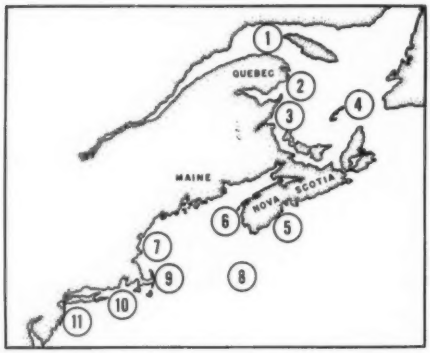

FIG. 1. Locations of sampling areas for adult herring.

the liver, and *Brachypallus crenatus*, a trematode which localizes in the stomach, were eliminated because of transiency, rarity, or inconspicuousness. Wherever possible, samples of 100 fish were examined for the 4 parasites mentioned above. Samples of adults have been grouped in the following geographic areas: (1) North Gaspe coast; (2) Chaleur Bay; (3) Northumberland Strait; (4) Magdalen Islands; (5) outer Nova Scotia coast; (6) Nova Scotia Fundy coast; (7) southern Gulf of Maine coast; (8) Georges Bank; (9) Cape Cod coast; (10) Block Island Sound; (11) New Jersey coast. Locations of these areas are shown in Fig. 1. In most cases, samples of adult herring were drawn annually during the period 1955–58 from spawning aggregations, although, because of local peculiarities of the fishery, some were taken at other times of the year. Samples of immature herring were taken during the study period from commercial catches and from experimental fishing catches along the Maine and New Brunswick coasts.

PARASITE TAGS FOR ADULT HERRING

Three parasites, all of which persist in the host for extended periods, have proved instructive, in that quantitative differences in their frequency of occurrence characterize adult herring from different geographic areas (Table 1). Percentages represent averages of many individual samples taken yearly from 1955 through 1958.

The first, a fungus parasite (*Ichthyosporidium hoferi*), has aroused interest because of its probable role in determining herring abundance. Acute infections are usually fatal within 1 month, but the chronic form of the disease has been found experimentally to persist for 18 months in some individuals. Infections reached epizootic proportions in the Gulf of St. Lawrence during the period 1954–56 and have declined rapidly since that time. The 1955–58 averages for that gulf thus include an outbreak peak and 2 years of declining incidence. The abundance of infections in Gulf of St. Lawrence herring contrasted with the very low incidence in the Gulf of Maine

TABLE 1.—AVERAGE PARASITE INCIDENCES IN ADULT HERRING, 1955–58

Area	Number of Samples	Number of Fish	Fungus (*Ichthyosporidium hoferi*) (percent)	Larval Cestodes (Trypanorhyncha)[1] (percent)	Larval Nematodes (Anisakinae)[1] (percent)
North Gaspe Coast (1)	4	400	15	0	18.5
Chaleur Bay (2)	15	1350	22	0	19
Northumberland Strait (3)	6	500	13	0	31
Magdalen Islands (4)	4	500	22	0	20
Outer Nova Scotia Coast (5)	11	950	3	2	76
Nova Scotia Fundy Coast (6)	6	550	2	2	64
Southern Gulf of Maine Coast (7)	14	1650	1	6	27
Georges Bank (8)	8	900	1	13	30
Cape Cod (9)	7	550	1	19	21
Block Island Sound (10)	4	400	1	46	12
New Jersey Coast (11)	4	400	1	31	14

[1] Further identification of these larval worms is difficult without experimental rearing of adults.

herring throughout the study period—a highly improbable situation if effective intermixing of fish from the two gulfs occurred. Examination of all available published data on the disease in western North Atlantic herring has disclosed evidence for periodic but not simultaneous outbreaks in both gulfs (Fig. 2), suggesting possible oscillation in abundance between the two areas.

Abundance of larval cestodes (order Trypanorhyncha) complemented fungus incidence, in that infections decreased with increasing latitude. The cestodes were abundant in the southern Gulf of Maine, but were not found in 4 years of sampling in the Gulf of St. Lawrence. Unlike the fungus organism, cestode abundance in particular regions remained remarkably constant throughout the survey period. Heterogeneity of fungus and cestode distribution and the reciprocal nature of this distribution indicate that there can be little if any interchange of adult fish between the two gulfs.

Larval nematodes of the subfamily Anisakinae were more abundant in Nova Scotia samples than in those from the Gulf of St. Lawrence or Georges Bank. As with larval cestodes, incidence of nematodes remained relatively constant in most regions during the survey period.

If each parasite frequency is considered as a separate population characteristic of herring from a particular geographic area,

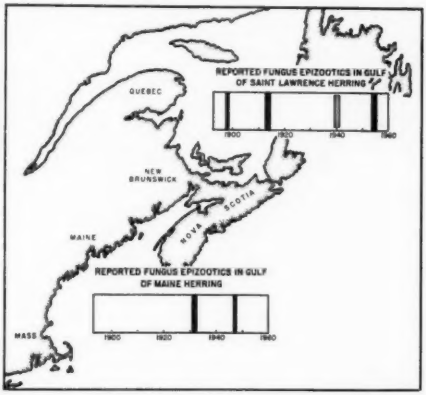

FIG. 2. Fungus (*Ichthyosporidium hoferi*) epizootics reported in herring of the Gulf of Maine and the Gulf of St. Lawrence. The Gulf of St. Lawrence outbreak which occurred about 1940 was not recorded in scientific literature, and is included here only on the strength of verbal reports from fishermen of the area.

it should be possible to achieve an approximation of maximum possible intermixing of adult herring between any two areas. Such a statistical manipulation of data must be confined to the survey period, should be limited to samples from spawning aggregations, and must assume relative permanence of the characteristics used. Within these restrictions we may conclude that intermixing of Gulf of Maine and Gulf of St. Lawrence adult herring approaches zero, and that

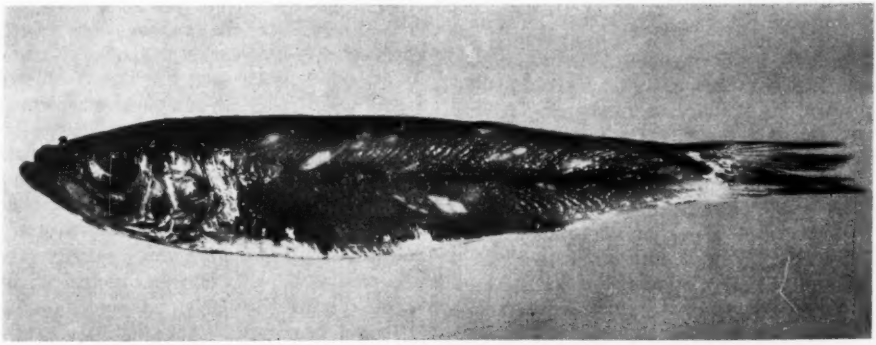

FIG. 3. Myxosporidian (*Kudoa clupeidae*) cysts in the flesh of 1-year-old herring.

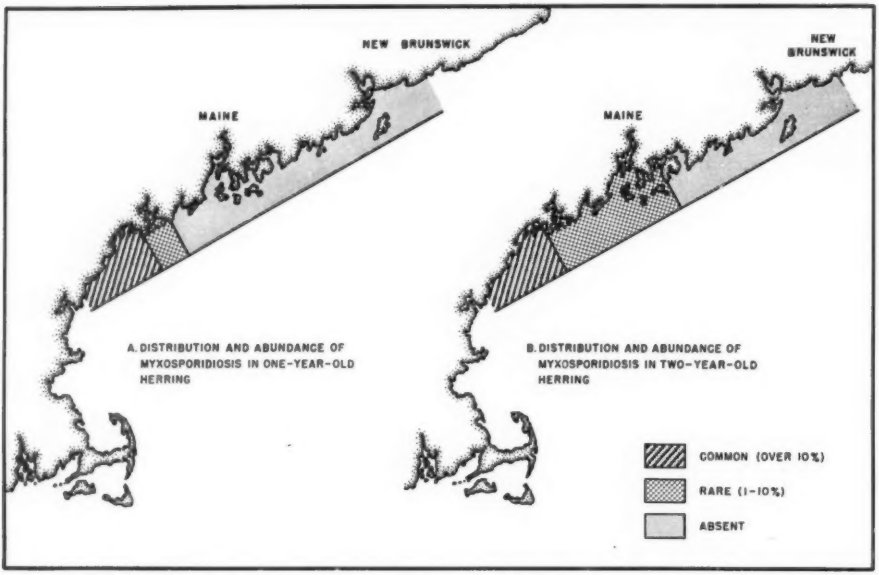

FIG. 4. (a).—Distribution of the myxosporidian *Kudoa clupeidae* in 1-year-old fish. (b).—Distribution of the myxosporidian in herring almost 2 years old.

only limited exchange between Nova Scotia and Georges Bank spawning aggregations could occur.

This, of course, is not genetic information, and tells us little of the true population structure of the species. It can, however, supply information about movements of adults, which should be a valuable supplement to population studies.

PARASITE TAGS FOR IMMATURE HERRING

Interest in movements of immature herring is derived primarily from the fact that the Gulf of Maine sardine-herring fishery concentrates almost entirely on 1- and 2-year-old fish. It is therefore important to understand as much as possible about movements of such herring during their brief period of economic importance. Also, considering possible future management of this species, knowledge of the homogeneity or heterogeneity of the stocks is necessary.

Two parasites have provided information about movements of sardine-size herring. The first, a myxosporidian (*Kudoa clupeidae*), comes close to being an ideal "natural tag" for such fish. It is easily visible (Fig. 3), is acquired early in the first year of life of the host, persists for at least 2 years, does not cause differential mortality, and, most importantly, is distributed discontinuously in immature Gulf of Maine herring. Infections in 1-year-old fish have been found only along the western Maine coast (Fig. 4a). When fish of the same year class were sampled almost a year later, infections were found only as far east as Mount Desert Island (Fig. 4b), giving an exact picture of limited eastward movement during the intervening period. Study of myxosporidian distribution in two year classes (1954 and 1955) gave comparable results. Seasonal examination of the distribution of this parasite in 1957–58 provided an even more precise picture of just when the limited movements occurred (Fig. 5).

Larval nematodes (Anisakinae), already discussed as "natural marks" for adult her-

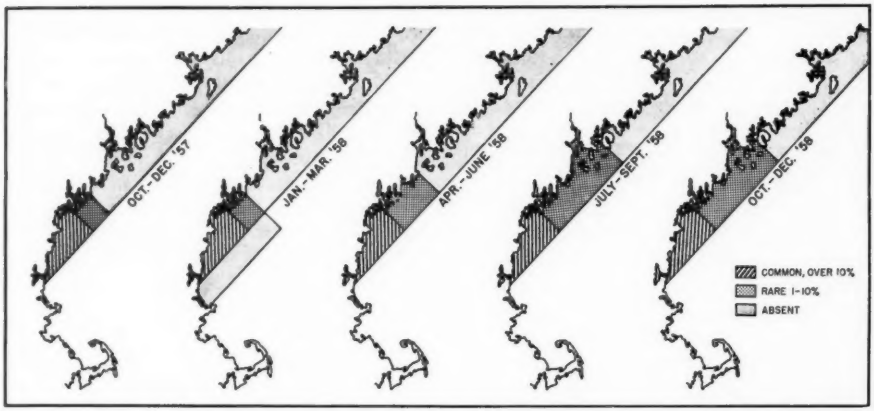

FIG. 5. Distribution of the myxosporidian in herring of the 1956 year class, sampled every 3 months during the period when its members were economically important as sardines.

ring, have complemented the picture of myxosporidian distribution. Examination of the same samples used for the myxosporidian study in 1955 and 1956 disclosed that larval nematodes were more numerous in 1-year-old fish from eastern Maine than in those from western Maine. Examination of fish of the same year classes almost a year later disclosed the persistence of greater numbers of worms in herring from eastern Maine. Incidences in the 2-year-old fish from both areas were higher than in 1-year-olds, with "western" fish showing a proportionally greater increase in worm incidence than "eastern" fish (Fig. 6). If it is assumed that there is a constant increase in numbers of worms with age in each area if no movement occurs, the data suggest that some of the more heavily parasitized eastern herring could have moved westward during the intervening period. Although other factors may be important, this could account for the disproportionate rise in worm incidence in western fish.

In summary, myxosporidian and nematode incidences indicating little eastward movement of herring that had spent their first year of life west of Penobscot Bay, but possibly greater westward movement of fish that had spent their first year east of that bay. For the 1954 and 1955 year classes, incidences of myxosporidian infections in western 2-year-old fish were only slightly over half those found in 1-year-old fish (Sindermann, 1957b), while nematode incidences in western 2-year-olds increased disproportionately over those found in 1-year-olds, when compared with their eastern counterparts. Both these findings suggest possible movement of eastern fish westward during their second year of life,

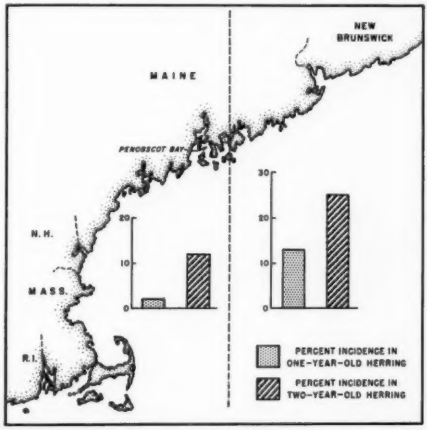

FIG. 6. Incidence of larval nematodes in 1- and 2-year-old herring from the eastern and western Maine coast.

but myxosporidian distribution alone precludes any major eastward movement during the period. It is also possible that long-term changes in the pattern of movements could occur, and that a continuing examination of nematode and myxosporidian incidences in each year class would provide some indication of this.

DISCUSSION

Studies of fish populations and migrations, of great importance to intelligent manipulation of marine resources, have been based traditionally on tagging and morphological characteristics. It seems reasonable that the greater the number of criteria used, the closer to reality will the conclusions become. The research summarized in this paper was designed to assess the value of parasites as "natural tags" for population and migration studies. There are, of course, many difficulties inherent in the use of parasites as tags. They may provide little information about extremely local movements of fish. Also, information about the duration of the parasite in the fish host must be available, as well as some knowledge of infection rates.

On the other hand, parasitological examination of a commercial marine fish species for the existence of "natural marks" may have certain advantages over an extensive tagging program. The primary advantage is one of lower cost, since tagging programs are expensive, while parasite studies may be made with samples from the commercial fishery, and need not involve vessel time—often the principal consumer of research funds. Examination of parasite distribution may also make a real contribution by furnishing advance clues about fish movements, which may be exploited in later tagging programs. Attempts to tag deepwater fishes such as the Atlantic redfish (*Sebastes marinus*) in their deepwater environment have not been successful; parasite tags should be of particular value to such investigations, and some insights have already been gained through this method (Templeman, 1950; Perlmutter, 1953; Sindermann, in press).

In some cases the absence of a parasite in an area may indicate lack of intermixing of fish from adjacent areas. For example, in our data, larval cestodes (Trypanorhyncha) were absent from Gulf of St. Lawrence herring samples, but were abundant in the southern Gulf of Maine samples. This discontinuity could only be maintained by lack of any effective movement of fish to the Gulf of St. Lawrence from areas where the parasite occurs. Usually, however, the situation is not as definitive. Most parasites occur throughout the host range, but in widely varying abundance. In this case, determination of average incidences in each area for several parasites can provide a maximum estimate of intermixing. For example, herring spawning on the coast of Nova Scotia had more than twice the numbers of larval nematodes of fish spawning on Georges Bank, but less than one-fifth the numbers of larval cestodes. This suggests that maximum possible interchange of adults between these two areas is slight, otherwise greater homogeneity would exist. It is therefore the composite of frequencies of several parasites that characterizes fish from a geographic area, and that may be compared with composites from other areas to obtain an indication of maximum possible intermixing.

Parasite frequencies, then, can provide a means of estimating or calculating maximum possible movement, but the actual movement may be much less. As is true of most methods for the study of marine fish, a parasitological study by itself would rarely produce definitive answers to population and migration problems. However, when parasitological data are combined with information gained from the use of other techniques, such as tagging and meristic studies, a significant contribution may be made.

It seems pertinent to this consideration that a concurrent serological study of herring, particularly of erythrocyte antigens, has provided support for some of the conclusions from parasitological data (Sindermann and Mairs, 1959). Quantitative differences in frequencies of fish with certain blood types have pointed to the existence

of two subgroups of immature herring, with a transition zone in the vicinity of Mount Desert Island—a finding which parallels the parasitological results reported here. This tends to increase confidence in evidence from parasitology, although the ultimate test must lie in agreement or lack of agreement with conclusions drawn from the use of established criteria for population and migration studies.

SUMMARY

A study of parasite distribution and abundance in immature and adult sea herring was carried on from 1955 through 1958 to provide information about intraspecies groups and their movements. Lack of intermixing or interchange of adult herring from the Gulf of Maine and the Gulf of St. Lawrence was indicated by larval cestode and fungus incidences. Within the Gulf of Maine, herring spawning on Georges Bank were distinguishable from Nova Scotia spawners on the basis of quantitative and reciprocal differences in frequencies of larval nematode and cestode parasites. The distribution of two parasites—a myxosporidian (*Kudoa clupeidae*) and larval nematodes (Anisakinae)—in immature herring from the Gulf of Maine demonstrated the existence of two parasitologically recognizable groups and the lack of major migrations of such fish.

Examination of parasite distribution and abundance thus constitutes another technique, along with the more established methods of tagging and morphological examination, of possible value in assessing the degree of discreteness of marine fish populations and in determining movements or lack of movements of fish.

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EDITORIAL ACKNOWLEDGMENT

Some changes in the Editorial Board will be apparent with this issue. Members leaving the Board are C. H. D. Clarke, David A. Munro, Robert D. McDowell, and William H. Marshall. The Editor acknowledges with many thanks their invaluable assistance with manuscript reviews, and with matters of JOURNAL policy and style.—CHARLES M. KIRKPATRICK.

MINK MOVEMENTS AND POPULATIONS ON A MONTANA RIVER[1]

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A mink (*Mustela vison*) live-trapping program was conducted on the lower Madison River near Three Forks, Montana, from 1955 to 1958 to obtain information on movements and populations. Marshall (1936) and McCabe (1949) delimited the approximate sizes of home ranges of mink females in certain habitats and seasons in Michigan and Wisconsin, respectively. Observations on individual mink movements have been reported by Hibbard and Adams (1957) in North Dakota and by Ritcey and Edwards (1956) in British Columbia. Since home range is known to be influenced by habitat (Burt, 1940), it seemed desirable to secure information for the Madison River population which is subjected to an annual harvest by commercial fur trappers. Also, it was desirable to compare age and sex ratios of live-trapped minks with those of minks commercially trapped.

The writer wishes to extend thanks to Kenneth R. Greer and Fletcher Newby of the Montana Fish and Game Department for interest and guidance during the project. Also, thanks are extended to landowners in the study area and to commercial trappers who cooperated. The writer is indebted to Don C. Quimby, Montana State College, for his direction of the study and aid in preparing the manuscript. During the investigation the writer was employed by the Montana Fish and Game Department, under Federal Aid Project W-49-R.

Study Area

The study area is a 5.4-airline-mile section of the Madison River extending from a point southeast of Three Forks to the Highway 10 bridge 1.4 mi. east of that city (Fig. 1). Shallow, rapid areas less than 1 ft. in depth are common on the river. Depths over 5 ft. are rare. The current is relatively swift, the gradient being 16 ft. per mi. The water flow is kept almost constant by a dam located above the study area. The main channel closely parallels the western edge of the broad valley floor. No streams enter the Madison in the limits of the study area.

A large irrigation canal parallels the river channel at distances from 50 ft. to ¼ mi. A low dike 8–10 ft. high with a road along its course separates the canal and river.

The following trees and shrubs are predominant along the main channel course: black cottonwood (*Populus trichocarpa*), firmleaf willow (*Salix pseudocordata*), prickly rose (*Rosa acricularis*), buckbrush (*Symphoricarpos albus*), wild licorice (*Glycyrrhiza lepidota*), and skunkbrush (*Rhus trilobata*). Several emergent and submerged aquatics are present along the stream banks and in the slow backwater areas, including common cattail (*Typha latifolia*), common reedgrass (*Phragmites communis*), horsetail (*Equisetum fluviatile*), American bulrush (*Scirpus americanus*), reed canary grass (*Phalaris arundinacea*), American sloughgrass (*Beckmannia syzigachne*), Nebraska sedge (*Carex nebraskensis*), western waterweed (*Elodea occidentalis*), chara (*Chara* sp.), ceratophyllum (*Ceratophyllum echinatum*), and smartweed (Polygonum coccineum).

Methods

Trapping was conducted during the fall of 1955, summer and fall of 1956, 1957 and 1958, and winter and part of the spring of 1957 and 1958. Live-trapping activities were not conducted between November 1 and February 15 of any year because of

[1] A joint contribution from Montana State College, Agricultural Experiment Station, Project No. MS844, Paper No. 502, Journal Series; and the Wildlife Restoration Division, Project W-49-R, Montana Fish and Game Department.

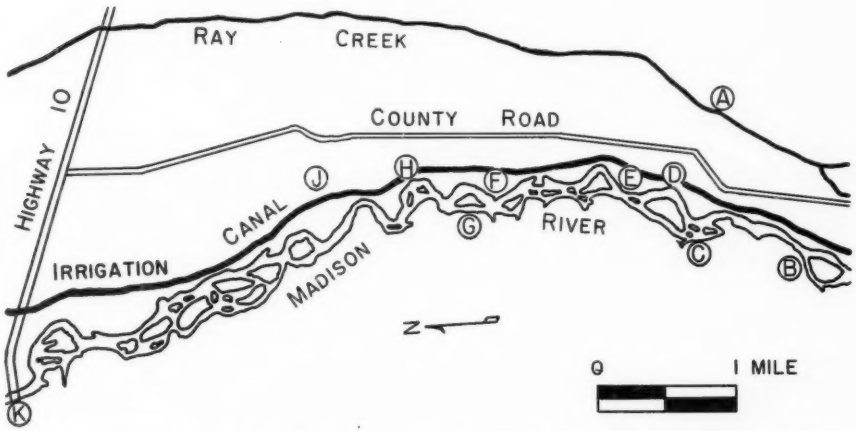

FIG. 1. Map of the Madison River study area showing the trap concentration areas A–K.

the commercial trapping season and difficulty in capturing minks immediately following the season.

Two types of collapsible, metal live-traps produced by the National Live-trap Company, Tomahawk, Wisconsin, were used. Most success resulted from use of the 6- × 6- × 24-in., double-door-model set with both doors open in runways. The 6- × 6- × 19-in. single-door type had some success when placed as a "blind set" (no daylight showing) in dirt banks or rock walls. Runway sets without bait proved successful during all seasons. Several traps were placed at each of the areas A–K (Fig. 1).

A numbered fish tag (size, 8- × 2-mm.) with the inscription M.F.G.D. (Montana Fish and Game Department) was placed in each ear of live-trapped minks. Each animal's ventral white spot pattern was recorded as additional aid in future identification (McCabe, 1949).

A collapsible wire cone facilitated the handling process. Each animal was aged (juvenile or adult), sexed and weighed (to nearest 25 gm.). The animals were then released at the trap site. Aging of live-trapped males was accomplished by palpation of the baculum (Petrides, 1950). Females were considered adults if they were lactating or had gray hairs on the napes of their necks (the gray hairs were thought to be due to injury by the male during copulation). No errors were found in age determination of 45 live-trapped and tagged minks which were captured by commercial trappers. The aging technique described by Greer (1957) was used on the carcasses to separate young of the year and adults.

All commercial trappers known to work the study area were contacted frequently to procure mink carcasses. I felt that nearly every mink taken from the area was recovered. Trappers were given maps for plotting positions of tagged animals taken.

For comparison between the juvenile : adult female ratio of non-commercially and commercially trapped areas, the Red Rock Federal Waterfowl Refuge 30 mi. east of Monida, Montana, was live-trapped during the fall of 1957 and summer of 1958. The refuge had not been commercially trapped for 4 years previous to 1957.

RESULTS

Trapping Success

One hundred eleven minks (54 juvenile males, 9 adult males, 35 juvenile females, and 13 adult females) were trapped and tagged. Four died at the initial capture and two at later recaptures. Seventy-six (66.1 percent) were recaptured at least once. Of

TABLE 1.—MINK LIVE-TRAPPING SUCCESS BY SEASONS

Season	Number of Trap Nights	Number Captured		Frequency of Times Mink Were Recaptured									
		Initial	Repeat[1]	1	2	3	4	5	6	7	8	9	10
1955													
Fall	308	9		2									
1956													
Summer	3480	9											
Fall	1040	10	1	1	3	1							
1957													
Winter	609	8	1	3	1	1		1					
Spring	626	7	5	2	1	1	1						
Summer	840	27	1	5	4	2	2	2		1	1		1
Fall	137	4	1	1									
1958													
Winter	421	4											
Spring	989	4	2	3									
Summer	546	30	2	7	3	3	4		1				
Fall	87	3	8	8	1	1							
Total	9083	115		32	13	9	7	3	1	1	1		1

[1] Captured during a previous season or seasons.

these, 31 were retaken in live-traps only, 23 in live-traps and by commercial trappers, and 22 by commercial trappers only. Live-trapping success was greatest during summer. A summary of the live-trapping results is given in Table 1. I felt that tag retention by minks was good. No minks were known to have lost both tags and 25 retained at least one tag over time periods ranging from 100 to 850 days.

Population Turnover

Column 4 in Table 1 indicates the number of minks live-trapped in more than one season (repeats). For the 18 animals involved, 14 were recaptured in each of 2 seasons only. Eleven of those repeats occurred in successive seasons while the remaining 3 skipped from 2 to 3 seasons before repeating. Four minks repeated in each of three seasons. One of the four was recaptured during three successive seasons. For the others, the number of seasons skipped before repeating ranged from one to four. Time intervals involved in the repeat histories of live-trapped minks ranged from 1 to 429 days. When the tagged minks captured by commercial trappers are included, the total seasons skipped between captures is raised to 8, and the time interval between captures to 850 days. It appears from the low percentage of tag returns in the second and third years following tagging that an almost complete turnover of the population occurred over a 3-year period.

Movements and Home Ranges

Seventy-six minks captured from 2 to 11 times each over periods of 1 to 850 days provided movement data. Nine of 45 tag returns by commercial trappers were from locations outside the study area. Six of the nine were taken during the 1957–58 season. That extensive emigration was possibly due to a population buildup resulting from poor commercial trapping conditions the previous two seasons. None of the adult males tagged were known to have left the study area. One adult female moved 24 airline mi. Six juvenile males travelled an average of 11.2 mi. (2–28 mi.). The two juvenile females moved 14.5 and 18.5 mi., respectively. All were taken in their new areas at least 3 months after their last capture in the study area. A 20-mi. movement in approximately 4 months in North Dakota by a tagged mink was reportedly due to drying up of potholes and a search for new habitat (Hibbard and Adams, 1957).

TABLE 2.—SUMMARY OF TRAPPING RECORDS FOR MINKS RECAPTURED ONLY ON THE STUDY AREA

Age and Sex	Number of Minks	Times Captured		Days between First and Last Capture		Miles between First and Last Capture	
		Range	Average	Range	Average	Range	Average
Juvenile ♂	35	2–7	3	7–484	114	0–3.0	0.3
Juvenile ♀	23	2–11	4	4–850	127	0–1.8	0.1
Adult ♂	2	3–6	5	58–224	141	0–2.7	0.6
Adult ♀	7	2–10	5	4–475	158	0–0.4	0.1

Table 2 summarizes movements of minks recaptured on the study area only. The diameter of the movement of any juvenile or adult male captured on the study area did not exceed 3 mi. Several juvenile males were commercially trapped in the immediate vicinity of tagging. There was evidence of home range overlap between juvenile and adult males, but none between adult males. Even during the breeding season, juvenile males were commonly captured in the same vicinity as an adult male.

Two adult females, each captured over a 2-year period, supplied data for home range computation (Fig. 2). The minimum home range of each was determined by connecting the outside points of capture and using a planimeter to measure the enclosed area. Female No. 25 was captured 7 times at Area C (19.3 a.) and Female No. 7, 10 times at Area E (50.4 a.). Area C had an abundance of excellent cover and a small irrigation ditch running through it. The type of terrain apparently had considerable effect on the size of calculated home range areas. Area E could have been marginal because of poor cover resulting largely from heavy grazing. No other female located there after the 1957 commercial trapping season when the population of the study area was lower.

Data on juvenile females indicated a maximum movement of 1.8 mi. within the study area. Movements of all but two of the remainder were less than ½ mi. The majority that were commercially trapped the same year as tagged were still in the immediate vicinity where they were tagged.

Instances of minks travelling in pairs were fairly common according to capture and sight records until late in the fall. Kits of either sex and an adult female with a female kit were the pairings found.

Populations

The live-trapping data do not indicate that all minks on the area were captured. The Lincoln Index was used to estimate the total population before harvest on the approximately 12.75-sq.-mi. study area. During the 1957 and 1958 commercial trapping seasons, 115 and 40 minks (Table 3) were trapped there, respectively, with 16 tagged animals taken in 1957 and 15 in 1958. In 1957, there were probably at least 39 (6 of 45 tagged during the year moved from the area) tagged animals available. The population was calculated to be 280 minks in 1957 and 109 in 1958. The 1957 figure was

TABLE 3.—RATIOS OF JUVENILES TO 100 ADULT FEMALES OBTAINED FROM LIVE-TRAPPING AND COMMERCIAL TRAPPING DATA

Date	Study Area Ratios	
	Live-trapping	Commercial trapping
MADISON AREA		
1955		
Fall	350(9)[1]	400(23)
1956		
Summer and Fall	470(18)	450(25)
1957		
Winter and Spring	550(15)	
Summer and Fall	440(32)	370(115)
1958		
Winter and Spring	500(8)	
Summer and Fall	900(33)	1130(40)
RED ROCK AREA		
1957		
Fall	50(4)	
1958		
Summer	150(7)	
Fall		250(12)

[1] Sample size in parentheses.

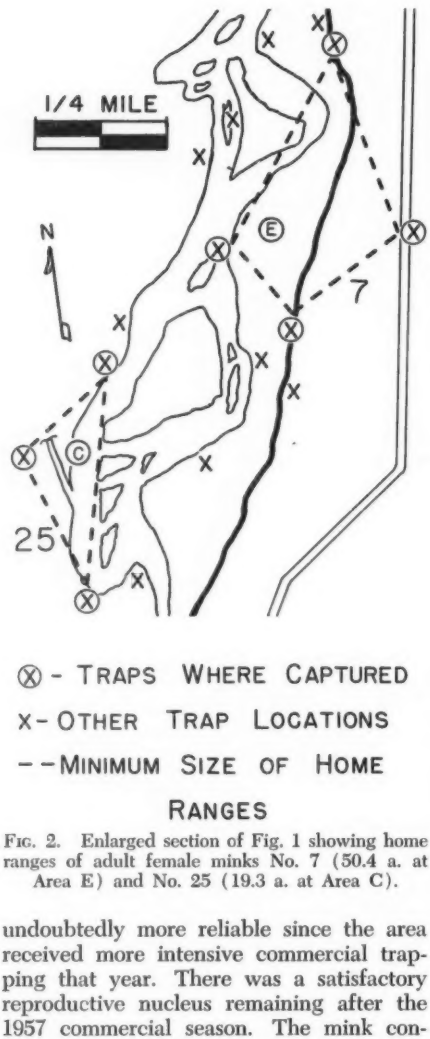

FIG. 2. Enlarged section of Fig. 1 showing home ranges of adult female minks No. 7 (50.4 a. at Area E) and No. 25 (19.3 a. at Area C).

undoubtedly more reliable since the area received more intensive commercial trapping that year. There was a satisfactory reproductive nucleus remaining after the 1957 commercial season. The mink concentration would have been 21.9 per section in 1957 and 8.5 in 1958. Marshall (1936) estimated 1.5 females per section after a heavy trapping season in Michigan.

A comparison of the juvenile : adult female ratios from live-trapping with those from commercial trapping on the Madison River study area (Table 3) shows similar fluctuations for the years 1955 to 1958. This might indicate that commercially trapped samples can be used as a qualitative expression of reproductive success.

The juvenile : adult female ratios obtained from minks live-trapped and commercially trapped in 1957 and 1958 on the Red Rock Federal Waterfowl Refuge were much lower than those for the Madison study area (Table 3), possibly because of lack of commercial trapping on the former.

Greer (1956) found that juvenile minks form a greater percentage of the harvest during the early season than later, and weather permitting, the majority of the total harvest is taken early in the season. Commercial trapper returns of tagged minks on the Madison River study area substantiated this. All of the 20 returns (25 percent adults) in 1957 and 80 percent of the returns in 1958 (12 percent adults) were recorded during the first two-fifths of the season.

Reproduction

Enders (1952) reported that "mink are sexually mature by February or March at approximately 10 months of age and their breeding season extends from late February through the first week in April." The first appearance of a live-trapped male that appeared to be breeding in 1957, on the basis of appearance of the external genitalia, was on March 2, and the date of last activity was March 22. In 1958, breeding activity was apparent by March 1 (three males captured within a few days). From the appearance of the vulva, an adult female captured on February 21, 1957, was not in heat, and another captured on April 7 appeared to be past heat. All of the juveniles live-trapped during the above periods possessed the same characteristics of the external genitalia as did adults.

The "family groups" (adult female and kits) apparently remained together until late August. After that, live-trap captures on trap concentration areas decreased and some of the kits, particularly males, were captured in other areas. The data from 8 mink litters indicated an average of 4 kits per litter (2–8). The male : female ratio

TABLE 4.—AVERAGE WEIGHTS (GRAMS) OF MINKS LIVE-TRAPPED DURING DIFFERENT TIME PERIODS

Time Period	MALE		FEMALE	
	Juvenile	Adult	Juvenile	Adult
July 16–31	675(4)[1]	1100(1)	500(4)	
August 1–15	775(22)	1075(3)	600(27)	550(12)
August 16–31	800(20)	875(1)	525(23)	550(12)
September 1–15	900(13)	1175(1)	550(10)	575(6)
September 16–30	975(7)	1175(1)	600(6)	600(2)
October 1–15	1000(7)	1075(2)	575(7)	575(4)
October 16–31	975(8)	1350(2)	650(4)	625(2)
February 17–28	1175(2)		600(1)	625(3)
March 1–15	1200(4)	1375(3)		650(3)
March 16–31	1200(14)	1200(3)	550(1)	625(2)
April 1–30	1125(3)	1150(1)	650(2)	600(4)
Average		1150		600

[1] Sample size in parentheses.

for the 32 juveniles (18 males, 14 females) was 128.6 males per 100 females. Through contact with mink ranchers (successful ones), Enders (1952) found an average of 4.48 kits per litter, and the male : female ratio at 8 weeks of age was 104 : 100. He also reported national averages of 3.2 kits per litter in 1949 and 2.8 in 1950.

Weights

Enders (1952) stated that "mink bear litters in early May and kits grow very rapidly during the first 8 weeks; then more slowly and have attained sub-adult size by the end of November."

Juvenile females in this study attained the average weight of adult females by the middle of August at approximately 4 months of age (Table 4). Juvenile males, however, did not attain the average weight of adult males until sometime between November 1 and February 28.

The largest adult male captured weighed 1475 gm.; the smallest, 875 gm. One adult female weighed 275 gm. Otherwise, the smallest adult female weight, which was 450 gm. recorded during the middle of August, was possibly due to having raised several kits. An obviously pregnant juvenile female was captured near the study area, and weighed 850 gm. on April 23, 1958.

The effect of live-trapping on body weight was not very pronounced, as illustrated by the history of a mink captured 8 times between March 17 and April 3, 1957. Its weight varied from 1125 to 1275 gm. during that period. The heaviest weight was recorded on the last capture.

SUMMARY

From 1955 to 1958, a mink live-trapping study was conducted on the Madison River, Montana. Seventy-six of 111 tagged animals were recaptured. Data indicated an almost complete population turnover in 3 years. The diameter of the movements of any male within the study area did not exceed 3 mi. Home ranges of 19.3 and 50.4 a. were determined for two adult females. Preseason populations were calculated to be 21.9 and 8.5 minks per section in 1957 and 1958, respectively. The height of the breeding season occurred in March. Juvenile females attained the average adult weight in about 4 months, juvenile males between November 1 and February 28.

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RELATION OF SUMMER RANGE CONDITION TO MULE DEER HERD PRODUCTIVITY[1]

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The plague of deer starvation on overbrowsed winter range is well known through numerous published reports. Less well known or understood is the fact that poor summer range may also drastically reduce deer herds—not through starvation but by lowering the productivity of the herds.

The importance of summer range condition to deer productivity has not come to attention in the western mountainous area of the United States for at least two understandable reasons: (1) On most herd units the summer range of mule deer (*Odocoileus h. hemionus*) far exceeds the limited winter range in grazing capacity; and (2) poor summer range produces "hidden losses" rather than the dramatic spectacle so commonly a part of "tough winters." This study attempts to evaluate the effect of summer range condition on mule deer herd productivity and to focus attention on its importance in deer management.

Morton and Cheatum (1946) reported that on good range in New York as many as 39 percent of fawns were bred, as compared to fewer than 4 percent on less adequate range. Further study in New York by Cheatum and Severinghaus (1950) also showed that white-tailed deer on poor range have a lower rate of productivity than those on range having an adequate supply of nutritious forage. Severinghaus (1951), using an 86-acre enclosure in New York State, found that the annual rate of increase for white-tailed deer was 1.9 fawns per doe during a 2-year period when natural foods were abundant. During a 2-year period after the enclosure was overbrowsed and just enough food was available to sustain the population, the rate of increase was only 0.43 fawn per doe. Malnutrition was the only observable cause for the decrease in productivity.

Goodrum and Reid (1958) reported an annual count of only 5 deer for 3 consecutive years in a severely overstocked 70-a. enclosure in Mississippi. During this period either no fawns were produced, or they failed to survive. However, in the fourth year, following a bumper acorn crop, three fawns survived. Taber (1953) reported that productivity of black-tailed deer in California was 147 percent on open brush type interspersed with herbaceous cover, compared to 84.3 percent in mature brush type with little herbaceous feed.

All the above studies were of resident deer using the same general range, both summer and winter. Overuse of forage in winter would reduce that available at other

[1] Contribution from the Utah Cooperative Big Game–Livestock Range Relations Project.

seasons and possibly affect breeding and conception as well as fawn survival. By contrast, the study we are reporting is of migratory deer and their productivity on two strikingly different summer ranges.

Mule deer in the mountainous West generally have distinct and different summer and winter ranges. Commonly the winter range is rather depleted but the summer range is more nearly adequate. Under these conditions deer may enter the fall breeding season in good condition and have a high rate of breeding success (Jensen and Robinette, 1955). However, herds on depleted winter range often suffer severe fawn mortality at birth or shortly afterward because of malnutrition (Lassen, *et al.*, 1952; Dasmann and Blaisdell, 1954).

The effects of nutrition and animal condition during the breeding season have been demonstrated in reproduction of livestock. Clark (1934) found that flushing (placing animals on high nutritional diet for a short period) increased the rate of ovulation if ewes were thin, but not if they were in good condition. Miller, *et al.* (1942) reported that yearling lambs on low protein diet failed to breed because they were losing weight and growth had not been completed. Low protein, plus low phosphorous, diet resulted in an unsatisfactory lamb crop. Several range–livestock studies (Culley, 1937; Hurtt, 1951; Hutchings, 1954) attribute low calf and lamb crops largely to inadequate forage.

Effects of summer range condition on productivity of migratory mule deer have been implied by studies of resident deer and of livestock. However, little documented information about migratory herds has been available hitherto.

TECHNIQUES USED

Two areas, as different in summer range condition as could be found, were selected for the purpose of studying the effect of this difference on herd productivity. The Antimony unit in south-central Utah, severely overgrazed by both deer and livestock for many years, represents the poorest summer range available. By contrast, the Sublett unit in southern Idaho (including the Black Pine Division), generally supports very good deer forage and is one of the better deer summer ranges in the region. The two areas contain the same major types, and these types are rather similar except for range condition. In severe winters, deer herds on both of these units are forced onto very poor range composed chiefly of sagebrush (*Artemisia tridentata*) and Utah juniper (*Juniperus osteosperma*). Parts of the Antimony winter range were more severely depleted than the Sublett. However, in open winters, such as occurred during the period of study (1954–56), deer herds on both ranges had access to fair forage on areas at intermediate elevations, and winter losses were very light.

Comparison of forage conditions on the two summer ranges was made in summers of 1954 and 1955 by sampling representative major types common to both ranges, using the weight-estimate method (Pechanec and Pickford, 1937) on random line-plot transects. (Sampling was done in midsummer when important deer forage species had reached maximum growth.) Deer pellet-group counts were made on these same transects as a relative measure of deer use.

Reproductive tracts were collected from deer of both herds during special and regular hunts. From fetus counts and examination of corpora lutea and corpora luteal scars, the fetal and ovulation rates were determined for different age classes of deer. Weights of deer were also taken as an indication of condition in the fall prior to the breeding season.

RESULTS

Range Condition

Forage was classified as good, fair, or poor in accordance with criteria proposed in numerous unpublished studies of deer food habits in similar types in Utah. Deer eat very little grass in summer and prefer the more palatable forbs, if available, for the bulk of their diet. As forbs become mature and dry, deer turn to browse for their chief forage.

Comparison of the weight of forage per

TABLE 1.—POUNDS OF AIR-DRY FORAGE PER ACRE AND DEER USE[1] ON DEPLETED ANTIMONY AND GOOD SUBLETT DEER SUMMER RANGES, 1954–55

Forage	ASPEN		CONIFER-ASPEN		BROWSE	
	Antimony	Sublett	Antimony	Sublett	Antimony	Sublett
Total grasses and sedges	109	152	24	406	115	324
Good forbs	14	37	7	21	20	45
Fair forbs	15	41	5	66	229	385
Poor forbs	14	7	2	6	12	51
Total forbs	43	85	14	93	261	481
Good browse	11	985	9	64	42	644
Fair browse	8	71	7	36	112	274
Poor browse	—	—	4	—	118	241
Total browse	19	1,056	20	100	272	1,159
Total herbage	171	1,293	58	599	648	1,964
Total good forage	25	1,022	17	85	62	688
Total fair forage	24	112	12	102	445	466
Total good and fair deer forage	49	1,134	29	187	507	1,154
Use per acre (deer days)	9.5	5.9	8.7	4.5	28.0	12.5

[1] Estimated from pellet-group counts on the basis of 15 pellet groups per deer day.

acre on the two ranges (Table 1) shows that in every classification the Sublett range was far superior to the Antimony. Essentially the same good, fair, and poor species grew on both areas. However, the Sublett range contained a greater variety of less important species. Good forbs found on both ranges included the following: Engelmann aster (*Aster engelmanni*), geranium (*Geranium richardsonii*), valerian (*Valeriana occidentalis*), Wyoming paintedcup (*Castilleja linariaefolia*), and columbine (*Aquilegia coerulea*). Good browse species found on both areas included aspen (*Populus tremuloides*), serviceberry (*Amelanchier alnifolia*), myrtle pachistima (*Pachistima myrsinites*), creeping mahonia (*Mahonia repens*), and wild rose (*Rosa* spp.).

Deer forage was several times more abundant on the Sublett range than on the Antimony. Forage classed as good was 17 times more abundant, and good and fair forage combined was more than 4 times more abundant. Several of the good forb and browse species that were abundant on the Sublett range occurred only as remnants on the Antimony. Furthermore, deer days' use per acre was less on the Sublett range (Table 1). The outcome was that by fall, deer on the Sublett range still had adequate good forage; but at Antimony the better forage had been heavily utilized and, after the latter part of August, deer were forced to subsist mainly on less desirable species.

Weights of individual deer on the two areas reflect the difference in available forage (Table 2). Weights of deer at Antimony averaged only 65 to 90 percent of weights of deer at Sublett; differences in weight varied with sex and age classes. Most of the deer at Antimony were weighed late in September each year; deer at Sublett were weighed three weeks later. This time lapse could account for some difference in weight. However, 17 fawns taken from the Antimony area in a September hunt weighed almost exactly the same by sex class as 7 fawns taken 3 to 4 weeks later in the regular October hunt of the same year. It therefore appears unlikely that the Antimony deer would have changed weight appreciably in the 3-week period.

In the fall of 1954 and of 1955, hunters

TABLE 2.—AVERAGE FALL WEIGHTS OF DEER (pounds, hog dressed) BY SEX AND AGE CLASSES FOR ANTIMONY AND SUBLETT RANGES

Deer range	FAWN		YEARLING		2-YEAR-OLD		3 YEARS AND OLDER	
	Buck	Doe	Buck	Doe	Buck	Doe	Buck	Doe
ANTIMONY								
Number sampled	14	9	12	8	6	5	10	15
Average weight	41	36	78	70	103	82	149	93
SUBLETT[1]								
Number sampled	16	11	14	7	14	10	27	12
Average weight	57	55	108	85	140	96	175	103
Percent:								
Antimony/Sublett	72	65	72	82	74	85	85	90

[1] Weights for deer at Sublett furnished by Dale L. Tanner, Idaho State Department of Fish and Game.

complained frequently of the poor condition of deer on the Antimony range, particularly the wet does and older deer. The more palatable forbs and shrubs had been utilized 80 to 90 percent by September 1. With the breeding season still several weeks ahead it was evident that deer at Antimony would have inadequate diet and would enter the rut in poor condition. By contrast, deer on the Sublett division had plenty of good browse in the fall. During a postseason hunt in January 1954, after the rutting season, deer from the Sublett were reported in good condition; many does showed good fat deposits on the kidney and brisket.

Herd Productivity

Ovulation rate per doe on the depleted Antimony range was only 67 percent of the rate on the good Sublett range (Table 3). The consistently low rate over a 3-year period indicates that low production is usual for this depleted range. In contrast, the consistently high ovulation rates (together with high counts of corpora luteal scars, corpora lutea, and fetuses) indicate a usual high rate of productivity of deer on the good range.

Fetus production rate per doe was similar to ovulation rate—only 64 percent as great on the Antimony range as on the Sublett (Table 4). Although the samples of ovulation and fetal rates are small, they were consistently high on the Sublett and low on the Antimony, with large differences between the two areas. The statistical differences between samples or years on the same area were not significant, but the differences between areas proved to be highly significant by the Chi-square test.

Three sets of triplets were found among the 24 mature does (Table 4) examined for pregnancy on the Sublett area in 1956, but no triplets were found in the sample of 33 does from Antimony. In a previous sample of 677 does from central Utah, only 1 percent had triplets, and the average fetal rate was 1.52 (Robinette, *et al.*, 1955). All nine Sublett yearlings examined were pregnant, five of them with twins. Of the eight Antimony yearlings, only five were pregnant and all had single fetuses. The greater difference in productivity noted for yearlings on good range as opposed to the comparison on older deer confirms the findings of others (Morton and Cheatum, 1946; Cheatum and Severinghaus, 1950) that productivity of the youngest producing age class reflects range condition more sensitively than that of the older age classes.

Further evidence of the herd differences in productivity is indicated by fawn counts. On the Antimony range, 80 does with 40 fawns were classified in a pre-hunting season count in September 1954; in 1956, 82 does with 42 fawns were classified. This average of 0.51 fawn per doe is considerably less than the average to be expected from mule deer. Classification data from less depleted ranges in Utah show averages of 0.75 to 1 fawn per doe. Although no comparable pre-hunt counts are available for

TABLE 3.—OVULATION RATES IN DOES OF BREEDING AGE[1] ON SUBLETT RANGE WITH ADEQUATE FORAGE, AND ON DEPLETED ANTIMONY RANGE

Collection	Number of Does	Corpora Lutea or Corpora Luteal Scars	Rate per Doe
SUBLETT			
1954 pregnancy study	16	29	1.81
1954 hunt data	11	22	2.00
1956 pregnancy study	14	29	2.07
Total	41	80	
Average			1.95
ANTIMONY			
1954 hunt data	42	60	1.43
1955 pregnancy study	26	33	1.27
1955 hunt data	27	32	1.19
1956 pregnancy study	19	24	1.26
Total	114	149	
Average			1.31
Percent: Antimony/Sublett			67

[1] Animals less than 1 year old at breeding season were excluded.

the Sublett range, we do have evidence of high fawn production. In a postseason hunt in January 1954, the classified kill included 58 does and 71 fawns, or 1.22 fawns per doe. Since western hunters prefer large deer, they kill disproportionately fewer numbers of fawns than does in most regular season hunts; however, this may not apply to postseason hunts. At any rate, the figures above indicate a high percentage of fawns. Also, following the 1950 Sublett hunt, Diem (1952) classified 96 does with 140 fawns, a ratio of 1.46 fawns per doe. This number is higher than our fetal studies indicate, and probably is not representative of the herd; but it certainly indicates a high fawn crop. This unusual proportion may result from a proportionately greater harvest of does in the regular hunting season.

We believe that range conditions, especially production and utilization of the preferred forage species, are a much better guide to proper stocking than reproductive rates of even the youngest class of fawn-producing does. Although reproductive rates may be used to supplement range condition records, our observations have shown that localized overuse on winter range areas can occur for several years before decreases in fawn crops become noticeable. Robinette (1950) found that herd productivity of mule deer on the Fishlake National Forest in Utah remained stable for at least 2 years after much of the winter range was observed to be in critical condition. He attributed the decrease in fawn crop to inadequate summer forage since the decrease occurred at the time overgrazing became noticeable on summer range. Since successful breeding depends largely upon

TABLE 4.—FETAL RATES FOR YEARLING AND MATURE DOES OF ANTIMONY AND SUBLETT DEER HERDS, 1954–56

	YEARLING DOES		MATURE DOES		TOTAL DOES	
	Antimony	Sublett	Antimony	Sublett	Antimony	Sublett
Does examined	8	9	19	24	27	33
Fetuses found	5	14	27	47	32	61
Fetal rate	.62	1.56	1.42	1.96	1.19	1.85
Percent: Antimony/Sublett	40		72		64	

thrifty condition of deer at rutting time, migratory herds coming from good summer and fall ranges would be expected to have a high ovulation rate regardless of shortage of forage the preceding winter.

Mortality among fawns, from the time of pregnancy examinations until late summer or fall, appears to have been greater in the Antimony herd. The computed loss for the Antimony herd is 40 percent. While only a few good fall fawn crop estimates are available for the Sublett herd, a computed fawn mortality, based on a conservative estimate of 100 percent fawn crop, is only 17 percent —less than half that noted for the Antimony herd.

Carrying the comparison of herd productivity to yearlings, we find that kill records on the Sublett for 1954–56 show that 35 percent of 95 does (fawns excluded) killed were yearlings, while an average of the kill for 1954–56 from the Antimony shows 28 percent of 401 does killed were yearlings. Of course, hunting pressures can greatly change the age-class composition of the herd and may have affected these data. However, hunting pressures were heavy on both areas during and immediately preceding the period of study, and the higher percentage of yearlings on the Sublett is believed to reflect a higher reproductive rate.

DISCUSSION

Adequate forage on the Sublett summer range and inadequate forage on the Antimony summer range is the only cause we have found for the difference in productivity of the two herds.

Plants differ considerably in nutritive qualities, both by site and by species and plant parts. Several studies have demonstrated the innate ability of foraging animals to select the more nutritious forage (Cook, *et al.*, 1953; Bissell, 1959). Thus while more than enough total forage apparently was available on both study areas for the deer present (15 lb. air-dry forage/deer day's use on the Antimony, and 76 lb. on the Sublett), the higher quality and greater availability on the Sublett range provided a more nearly complete and nutritious diet, which in turn produced heavier animal weights. The effect of a drastically reduced nutritional level upon fawn production as reported by Severinghaus (1951) has already been mentioned. Similarly, O'Roke and Hamerstrom (1948) reported productivity averaging somewhat more than 60 percent for the George Reserve herd during the first 6 years following stocking. Subsequent range deterioration resulted in a decline in herd productivity to an average of only 38 percent for the following 6 years.

Although we have no precise data on fawn survival on the areas studied, other studies have demonstrated that malnutrition results in heavy mortality of fawns at or soon after fawning time (Julander and Robinette, 1950; Longhurst, *et al.*, 1952). McCance and Alexander (1959) found that delayed onset of lactation and reduced rate of milk production by poorly fed Merino ewes substantially reduced the chance of survival of young lambs. Since the Sublett deer entered the winter period in much better condition than deer at Antimony, it is reasonable to expect that they would be in better condition at fawning time and be able to rear a higher percentage of their fawns. Thus it is logical that the difference in fawn survival for the two herds should be even greater than was indicated by the fetal and ovulation rates.

The fetal rate of 1.85 and ovulation rate of 1.95 per doe on the Sublett agrees closely with a rate of 1.9 fawns per doe for white-tailed deer on abundant feed reported for New York (Severinghaus, 1951) and the 2.0 fawns per doe in southern Michigan (Jenkins and Bartlett, 1959). This appears to be about maximum productivity for deer. To approach this rate on western ranges, a good summer range, capable of carrying deer in good condition into the breeding season, is necessary.

This study furnishes additional evidence that the greatest yield of big game animals can be sustained only by maintaining a proper balance of game numbers and forage supply.

SUMMARY

Productivity of two mule deer herds in Utah and Idaho was studied; one on severely depleted Antimony Mountain summer range in central Utah; the other on good summer range on the Sublett unit in southern Idaho.

Fall weights of Antimony fawn bucks and does were only 72 and 65 percent, respectively, of weights of the Sublett fawns. Weight ratios of yearlings were 72 percent for bucks and 82 percent for does. For 2-year-olds the comparable ratios were 74 and 85 percent, and for older deer the ratios were 85 and 90 percent.

Average ovulation rate per doe on the depleted range (1.31) was only 67 percent of that on the good range (1.95). Fetal rate per doe averaged 1.19 for the Antimony compared to 1.85 for the Sublett.

A good summer range, capable of carrying deer in good condition through the breeding season, is necessary for maximum herd productivity.

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MIGRATIONAL HOMING IN MOURNING DOVES

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That individuals of certain species of birds exhibit a marked tendency to return to the same geographic area year after year for breeding is well documented (von Haartman, 1949; Nice, 1937; Sowls, 1955). Only recently, however, has attention been given to determining the possible management implications of this phenomenon or to determining how large a segment of any given population exhibits this tendency. Hochbaum (1947; 1955) points out that there is a danger of "burning out" local breeding populations of certain species of waterfowl by too much hunting pressure applied in the fall before the local breeding adults have had a chance to disperse. Sowls (1955) studied the degree of homing exhibited by five species of surface-feeding ducks and discovered that certain species exhibited a greater tendency to home than others. He also found that the females exhibited a greater homing tendency than the males and that adult females were more precise than juvenile females. This is in contrast to the usual situation found in song birds where the adult males tend to home more precisely than the adult females (von Haartman, 1949).

Little has been published concerning the extent of homing exhibited by mourning doves (*Zenaidura macroura*). Stewart and Mackey (1953) recorded a pair which used the same nest site in two successive years. Austin (1951) concluded that doves exhibited "site tenacity" to the breeding grounds but his data are not based on extensive samples of nest-trapped adults. Tomlinson, *et al.* (1960) reported on a study of bait-trapped doves on a Missouri breeding area and concluded that all of the surviving males, and over 90 percent of the surviving adult females returned to the same local area that they had nested in the previous year. They assumed that juveniles returned to their natal sites only rarely. These Missouri conclusions may be subject to some question in that they are not based on nest-trapped birds, but the authors presented evidence of a low radius of mobility in the summer for adult doves and assumed that their bait-trap locations actually did represent the local breeding area for the birds involved.

The present study is an attempt to provide migrational homing data for mourning doves based on nest-trapped birds.

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Area and Methods

This study was conducted at the Madelia Research Center of the Minnesota Division of Game and Fish near Madelia, Minnesota. The study area consisted of an abandoned 160-a. game farm which is presently devoted to an experimental cropping pattern of corn, soybeans, and various hay crops. About 6 a. of the area are occupied by woody cover types consisting of one 3-a. woodlot composed of box elder (*Acer negundo*), various maples (*Acer sp.*), and other hardwood trees. Spruce (*Picea glauca*), pine (*Pinus ponderosa*), and juniper (*Juniperus occidentalis*) shelterbelts and landscape plantings occupy the remaining 3 a. of woody cover. These woody cover areas support large numbers of nesting mourning doves. The Research Center is located in a region of intensive agricul-

ture for corn and soybeans. Approximately 90 to 95 percent of the land area is occupied by cropland, pasture, roads, and other open non-woody cover types. The only woody cover types present consist of landscape plantings, shelterbelts, and farm woodlots of 1 to 6 a. usually located around the farm buildings. On the average, there are three to four of these farmsteads in a scattered pattern in each square mile. The Research Center grove is fairly typical of those in the general vicinity, but there is somewhat more conifer shelterbelt present than on the average farm. Nearly every farm woodlot or patch of woody cover in this area of the state has a breeding dove colony, but, to the author's knowledge, none has as dense a dove population as that on the Research Center. In the present study, only the Research Center woody cover was studied intensively. The nearest other woody cover consists of a mature maple–cottonwood (*Populus deltoides*) farm woodlot about ¼ mi. east and three other woodlots are about ½ mi. away.

During the nesting season, a complete search was made of all woody cover at weekly intervals in an effort to locate every mourning dove nest on the 160-a. area. The nests were tagged and the data recorded on standard forms. Adults were trapped on their nests in 1957, 1958, and 1959. Most of the birds were captured by use of mist nets (Harris and Morse, 1958), but some were captured using "Swank traps" (Swank, 1952) and in 1959 a few were bait-trapped and tagged with back tags modified from those of Blank and Ash (1956). These tagged birds often were re-observed on their nest sites. In 1957, trapping operations were conducted only during the month of June. In 1958, trapping was done intensively from early May through August, and in 1959, from mid-April through July when the study terminated. Trapping was restricted to the Research Center, so that conclusions on return rates and homing tendencies refer to the 160-a. area only. The bulk of the trapping effort was in the evening hours so that, in general, the trapping methods were biased in favor of adult females since they are in attendance at the nest during the evening more than males.

Although no intensive effort was made to determine what percentage of the dove population may have been using ground-nest sites rather than tree sites, it is felt that only an extremely small percentage nested in such situations. During the years of this study, concurrent investigations were also made of pheasant nesting activities. In the course of these studies, over 1,000 acres of various ground cover types were thoroughly searched for pheasant nests and only 3 mourning dove nests were found on the ground. Moreover, no dove nests were ever found on the ground in the vicinity of the woody cover areas although these areas were examined repeatedly incidental to the searches of the woody cover. I believe that the percentage of doves nesting on the ground was so small that error from this source in the homing rates as presented would be insignificant, and certainly the general conclusions would not be altered.

HOMING TENDENCY OF DOVES BANDED AS ADULTS

Regardless of sex, approximately 20 to 25 percent of the adult doves banded as breeders in one year were known to have returned to the same 160-a. area to nest the following year (Table 1).

This represents a *minimum* homing rate of 20–25 percent. The actual rate is higher than this because not all birds banded in one year survive and are available to return the next year. The mortality rates of Madelia Research Center doves are unknown, but banding returns on a national scale, exclusive of the southeastern states, indicate an annual mortality rate of approximately 51 percent for adult doves (Southeastern Assn., 1957). If it can be assumed that Minnesota birds have a similar mortality rate, it is possible to estimate how many of the banded doves may have survived to be available to return in subsequent years (Table 1).

When the data are corrected to account for mortality of banded birds from one year to the next, the homing rate of adults is

approximately 50 to 60 percent for the first year after banding, and based on very small samples, nearly 100 percent for the second year after banding. Thus, for example, in the first year after banding, of an estimated 18 adult males surviving, 10 were actually found nesting on the area (Table 1).

One more variable needs to be considered. Only a portion of the population of breeding birds at the Research Center were trapped in subsequent years. Thus, while some banded adults were recaptured each year, undoubtedly others were present on the area in the untrapped portion of the population. It is possible to estimate the total number of banded adults which were present on the area each year by applying the trapping figures for each year and for each sex-age category to the following formula:

$$\frac{\text{Total number of birds trapped}}{\text{Number of returns in trapped sample}} = \frac{\text{Total population present on study area}}{x}$$

$$x = \text{(Total number of banded birds probably present in population)}$$

In both 1958 and 1959, based on nest census data, an estimated 100 pairs of doves nested on the study area. In 1958, 33 adult males and 76 adult females were trapped during the summer, of which 1 male and 10 females had been banded as adults in 1957. Applying the formula to these data, I estimated that there were 3 males and 13 females present in the population which had been banded as adults in 1957. In 1959, 64 different adult males and 81 adult females were trapped of which 9 males and 14 females had been banded as adults in 1958. From the formula, it was estimated that a total of 14 males and 17 females were present in the population which had been banded as adults in 1958. Thus, combining the data for both years, a total of 17 banded males and 30 banded females were estimated to have been present in the population the first year after banding. By comparing the number of birds probably present to the number which probably survived, it is possible to calculate a "corrected homing rate" (Table 1). It is obvious that mourning doves have a rather high tendency to return to the same local area to breed each year. Table 1 indicates that virtually 100 percent of males still alive returned to the study area while only about 60 percent of the females returned. However, the fact that this is based on rather small samples, and that these estimates contain two assumed correction factors, undoubtedly tends to invalidate any apparent differences between the sexes. Regardless of the assumptions, it seems obvious that a high percentage of doves of both sexes tend to return to the same area to breed. These are essentially the same conclusions as those found by Tomlinson, *et al.* (1960) for the Missouri study.

Not only did the adult doves exhibit a high rate of return to the study area, but there was a marked tendency for individuals to nest in the same *part* of the study area where they had nested in previous years. In this study, measurements were made between the locations of nest sites for birds in the year of return and all known sites for previous years for the same bird (Table 2).

Eighty percent of the nest sites of returning adults were located within 200 ft. of sites used by the same bird in the previous year. Nearly 50 percent were within 50 ft. Several birds used the same nest in consecutive years. For consecutive years, the average distance between nest sites of the same adult was 154 ft. Birds which were found nesting on the area in the second year after banding had moved an average of only 300 ft. from sites used 2 years earlier. Seventy percent of these 2-year movements were within 200 ft. and 40 percent were within 50 ft.

HOMING TENDENCY OF DOVES BANDED AS NESTLINGS

While adult doves of both sexes which

TABLE 1.—MIGRATIONAL HOMING PERCENTAGES OF MOURNING DOVES (Corrected for an annual mortality rate of 51 percent for adults and 60 percent for nestlings and for probable banded birds present in the untrapped portion of the population)

Year after banding	Observation	Adult Male	Adult Female	Nestlings
First	Size of banded sample	37	104	512
	Estimated number surviving	18	51	205
	Number actually recaptured	10	24	3[1]
	Estimated number present on area	17	30	5
	Corrected homing rate	95	59	2
Second	Size of banded sample	5	38	323
	Estimated number surviving	1	9	61
	Number actually recaptured	1	7	1[2]
	Estimated number present on area	1	9	1
	Corrected homing rate	100	100	2
Third	Size of banded sample	No data	No data	143
	Estimated number surviving	No data	No data	14
	Number actually recaptured	No data	No data	0
	Estimated number present on area	No data	No data	0
	Corrected homing rate	No data	No data	0

[1] 1 male; 2 females; 2 additional females were bait-trapped but the location of their nests was not determined.
[2] 1 female.

had nested previously on the study area had a high migrational homing percentage, birds which had been hatched on the study area did not (Table 1). In 1956, 134 banded nestlings were fledged from the study area. In the three years that followed, none of these birds were captured on the area as breeding adults even though 63, 76, and 81 percent of the total estimated adult female population was trapped in 1957, 1958, and 1959, respectively.

In 1957, 180 nestlings were banded and, even though 76 percent of the females and 33 percent of the males nesting on the area in 1958 were trapped, no returns were obtained. One female that had been banded as a nestling in 1957 was found nesting in the area in 1959. In 1958, 189 nestlings

TABLE 2.—YEAR-TO-YEAR MOVEMENTS BETWEEN NEST SITES OF DOVES ORIGINALLY BANDED AS NESTING ADULTS

Distance Moved in Feet	One Year Later		Two Years Later	
	Number of Times Recorded	Percent of Total Occurrences	Number of Times Recorded	Percent of Total Occurrences
0	9	14	1	7
1–50	20	31	5	33
51–100	10	15	1	7
101–150	7	11	1	7
151–200	6	9	3	20
201–300	8	12	1	7
301–500	0	0	1	7
501–1000	4	6	1	7
1000+	1	2	1	7
Total occurrences	65		15	
Average distance moved in feet		154		300

were banded and in 1959 only 1 male and 2 females of this group were known to have nested on the study area, and 2 additional females were trapped in bait traps on the study area, but the locations of their nests were not determined (Table 1).

These data indicate a low homing rate for birds which had hatched on the study area. When the data are corrected for a mortality rate of 60 percent (Southeastern Assn., 1957) for the first year of life and 51 percent per year thereafter, and are further corrected to allow for banded birds possibly having been present in the untrapped residue of the population, the rate of return of birds banded as nestlings is on the order of only 2 percent (Table 1).

From the available data, it can be concluded that only a very small portion of doves entering their first breeding season returned to nest on the same 160-a. area where they were hatched. It is possible that many may have returned to the same general locality (perhaps the same county of the state) but whether or not this is true was not determined.

Additional evidence that doves entering their first breeding season did not home as precisely as those which had previously nested on the area comes from nest-site-location records. In all, four birds that had fledged from the study area were known to have nested on the area in subsequent years —three the first year after hatching, and one 2 years later. The three which returned the first year after hatching were two females and one male. These 3 were found nesting 1620, 1128, and 780 ft. respectively from the nests where they had been hatched the previous year—an average of 1176 ft. One female was found nesting 1140 ft. from the nest in which she had hatched 2 years before. These data contrast with average movements for returning adults of only 154 ft. in consecutive years and 300 ft. for nests 2 years later (Table 2).

SUMMARY

Adult mourning doves were trapped from their nests in 1957, 1958, and 1959 at the Madelia Research Center, Minnesota. When the data are corrected to allow for annual mortality of banded birds and for the presence of banded birds in the untrapped residue of the population, migrational homing rates of approximately 100 percent for adult males and approximately 60 percent for adult females were obtained. The average distance between nest sites of returning adults was 154 ft. in consecutive years and 300 ft. for sites 2 years later. In three years of trapping adults from nests, only 6 of 512 doves banded as nestlings on the study area were known to have returned in subsequent years. The average distance of the nest sites of 4 of these birds from the nests in which they had hatched was 1167 ft.

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DEER MILK COMPARED WITH SUBSTITUTE MILK FOR FAWNS[1]

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White-tailed deer (*Odocoileus virginianus*) reared artificially under prevalent practices seldom equal wild deer, or fawns raised by their dams, in either size or condition during their first season.

In raising fawns for our deer nutrition studies, much individual attention has been required to work out formulas satisfactory for small, weak, or long-abandoned fawns. Even the stronger, more adaptable fawns may not have grown so rapidly during the nursing period as those reared under natural conditions.

Most of our information about size and growth of wild New Hampshire fawns comes from those shot during the hunting season at ages of 5–7 months. With a few exceptions fawns we have reared for experimental work were as large as wild fawns of the same age, but it is possible that slow growth during the nursing period was offset by more rapid growth on high-quality concentrates after they started to eat grain. Average weight of our artificially reared fawns, at age 6 months, has been 80 lb. for bucks, 74 lb. for does. These weights are close to the estimated live weight of fawns taken in the harvests from 1951 to 1953: bucks, 81 lb.; does, 77 lb.

Diarrhea frequently presents a problem which may affect the entire herd. Pennsylvania (French, *et al.*, 1955), Michigan (letter, Mich. Cons. Dept., March, 1959), and Wisconsin (letter, Wis. Cons. Dept., March, 1959) also report digestive disturbances among artificially reared fawns. In general, New Hampshire fawns have been fed more concentrated formulas, more frequently, over a longer period, and have been somewhat heavier at equivalent ages than those raised in these states.

Rearing Methods

As substitutes for does' milk we have used whole cows' milk (pasteurized, homogenized, and raw, and variously enriched with egg or Pablum), powdered skim milk, diluted evaporated milk, registered baby foods, and "milk savers" of the type used for calves. The last may not have been given a fair trial since use was quickly discontinued when they were either refused or caused bloat. Human baby foods are perhaps the poorest approximation of the fawns' natural food.

Depending on their size, newly captured fawns were started with 2–4 oz. of any of the above rations every 4–5 hours. This amount was increased, as rapidly as possible without causing distress, to 8 oz. per feeding four times daily between 6:00 a.m. and 11:30 p.m. By August, the number of feedings was reduced to three per day. Through September, up to 12 oz. were fed twice daily. Starting in October, milk was gradually withdrawn, with weaning completed by October 15. Except in one test, described below, no fawns have been weaned earlier than 4½ months. Diet and schedule were adjusted to the individual.

Tests of More Concentrated Formulas

In the hope of improving efficiency in feeding, we analyzed a composite sample of does' milk collected from dead deer during the hunting season (Nov. 1–7, 1957). Compared with milk of domestic species, it tested extremely high in all constituents, but was similar to most analyses of deer milk in the literature (Table 1).

After regular milking has ended, radical changes in milk composition occur (Peter-

[1] A contribution of Federal Aid Project FW-2-R, N. H. Fish and Game Dept. Acknowledgment is due Henry A. Laramie and Forrest F. Fogg for collecting the sample of milk from wild deer; and Gilman K. Crowell, N. H. State Board of Health, for making the analyses.

TABLE 1.—AVERAGE PERCENT COMPOSITION OF MILKS OF SEVERAL SPECIES OF RUMINANTS

Species	Water	Protein	Fat	Sugar	Ash	Authority
Cow	86.21	3.77	4.45	4.86	0.72	Wright, *et al.* (1939)
Cow	87.90	3.13	3.65	4.50	0.72	Wright, *et al.* (1939)
Goat	87.14	3.71	4.09	4.20	0.78	Wright, *et al.* (1939)
Sheep	82.90	5.44	6.24	4.29	0.85	Wright, *et al.* (1939)
Reindeer	63.30	10.30	22.46	2.50	1.44	Wright, *et al.* (1939)
Deer	65.88	10.35	19.73	2.61	1.43	Olsen Pub. Co. (1957)
Deer (white-tailed)	67.77	11.92	15.06	3.75	1.51	Ruff (1938)
Deer (white-tailed)	66.51	11.50	18.00	2.22	1.77	This study (from dead deer)
Deer (mule)	79.60	—	8.30	—	1.44	Hagen (1951)

sen, 1950). Whether the wild does from which our November sample was collected were still suckling young, or how long since they had ceased to do so, could not be determined. Information on the length of the nursing period of deer is scarce. According to Severinghaus and Cheatum (1956), fawns occasionally nurse up to the next breeding season, or to about 5 months. A few were known to nurse for 6 months. They concluded that wet does observed in November were probably suckling fawns as late as November. My own limited observations of captive animals tend to support this conclusion. Fawns born here the middle of June were still nursing through the first week in November, but had ceased to nurse by the third week of the month.

During the rearing season of 1958, there was insufficient information on normal composition of does' milk to justify attempts to duplicate it. Nevertheless, several formulas, based on cows' milk with protein and fat arbitrarily increased by the addition of dry skim milk and "heavy" cream, were compounded. These were tested on one buck fawn for palatability and tolerability only, over a period of about 2 months. All were too expensive for general use. The two most concentrated formulas tested lower in both protein and fat than our November sample of deer milk.

All the formulas were eagerly accepted by the buck, and none caused digestive disturbance. Since the formulas were sometimes changed as often as every day or two, and the buck not intended for experimental use, no weights were taken. This fawn was a normal, healthy individual, but not outstanding in any observable way. From the age of about 2½ months he was fed undiluted evaporated milk until he was approximately 4½ months old, and thereafter maintained on the regular grain ration used by the N. H. Fish and Game Department for adult deer, except for the addition of some whole corn early in the winter. As a yearling he developed an excellent 8-point rack. Normally our yearling bucks are spike horns, although two, raised on whole milk plus egg and Pablum, developed six points.

Two does were raised entirely on undiluted evaporated milk. Three brands, practically identical in composition, were fed at random. The fawns were started on 1–2 oz. per feeding, but, as with the more dilute formulas, this amount was rapidly increased to 8 oz. By July, a month earlier than usual, feedings were cut to three per day, and by September 1 the fawns weaned themselves at the age of 3 months.

Four does, raised on whole milk, were chosen for comparison with the two raised on undiluted evaporated milk because of their original similarity in size, age and condition. Average weight of both groups was 9 lb. at an estimated age of 1 week, when received. All were in good condition, and at this age must have received colostrum.

The unquestionably superior health and general condition of the fawns fed evaporated milk suggested that digestive dis-

TABLE 2.—CHANGES IN COMPOSITION OF COW MILK AND DOE MILK WITH PROGRESSIVE LACTATION

Species	Stage of Lactation	Composition (percent)					Authority
		Water	Protein	Fat	Sugar	Ash	
Cow	Colostrum	76.2	17.0	3.3	2.50	1.04	Winton and Winton (1937)
	1 month	87.26	3.25	4.0	4.87	0.62	Winton and Winton (1937)
	End (13 mo.)	85.77	4.34	4.66	4.50	0.73	Winton and Winton (1937)
Doe	Colostrum? (24–48 hr.)	77.85	8.83	8.00	3.82	1.50	This study
	1 week	76.92	10.65	8.00	2.85	1.58	This study
	1 month	77.78	10.14	7.50	3.00	1.58	This study
	End (5 mo.)	66.51	11.50	18.00	2.22	1.77	This study

turbances may result from too dilute formulas, which cannot meet nutritional requirements without overtaxing the capacity of the digestive system. Evaporated milk furnishes about twice the nutrients per fluid ounce as whole milk does. However, evaporated milk is far below the indicated quality of does' milk. Therefore, an experiment was planned to compare the growth of fawns reared on evaporated milk with that of naturally reared fawns, and to secure additional data on the quality of does' milk.

COMPOSITION OF DEER MILK

A doe, trained to submit to the process of hand milking, produced twins in June 1959. Attempts to secure a sample of milk during the first 24 hours after parturition failed. On the second day a sample was obtained by milking while the fawns nursed. Two more samples, at the end of 1 week and 1 month, respectively, were obtained in the same manner (Table 2).

The 8.0 percent fat content of both June samples was close to the 8.3 percent reported for mule deer (Hagen, 1951), the only sample of deer milk definitely reported as collected early in the lactation period. However, the possibility of error as regards fat content, arising from the method of sampling, cannot be overlooked. Winton and Winton (1937) questioned the validity of an analysis of elephant milk where samples could be obtained only while the young animal was nursing.

In cows, the strippings may contain several times as much fat as the first milk drawn (Petersen, 1950), but incomplete milking will not affect non-fat solids (Sommer, 1938). Every effort was made to collect the doe's milk over the entire nursing period, and to offset any effect of uneven milking intervals, samples were compounded from milk taken at each feeding over a 24-hour day. Despite all care, very likely not all the strippings were removed, and the indicated fat content may be somewhat below the true fat content. Nevertheless, the analyses are probably more indicative of the true quality of normal deer milk than analyses of samples collected at the end of lactation, when greater concentration is to be expected.

The tremendous increase in fat between the beginning and end of lactation may be a characteristic of the species resulting from the combined influence of winter weather and the end of lactation, both of which factors increase the fat content of cows' milk (Maynard, 1947), although to a much lesser degree.

A point of special interest is the protein content of the milk immediately after parturition. In cows, the outstanding difference between colostrum and normal milk is its high protein content (Table 2). The colostrum period lasts for about 10 days, with composition becoming more nearly normal with each successive milking. Deer milk, collected 24–48 hours after parturition, tested nearly 2 percent lower in protein than the second sample taken at the end of one week. Since there is no reason to question the analyses as regards protein, it must be concluded that the difference in

protein content of colostrum and normal milk is much less in deer than in cows, or that deer milk becomes normal much more rapidly, perhaps as a result of more frequent milkings.

At the end of one month, total solids of the deer milk were practically the same as on the second day after fawning, while cows' milk showed an 11 percent drop over the same period, mostly accounted for by the decrease in protein. Changes in lactose and ash, as lactation progresses, appear to be roughly in the opposite direction for deer and cows' milk.

The possibility of differences between the milk of tame and wild does, arising from differences in feed, is small. Animals tend to produce milk of composition characteristic of the species regardless of diet (Maynard, 1947).

COMPARATIVE EFFICIENCY OF DEER MILK AND SUBSTITUTES

Composition of undiluted evaporated milk (Avg. percent: water, 73.8; protein, 7.0; fat, 7.9; sugar, 9.8; ash, 1.5) was somewhat closer to that of normal deer milk than originally supposed, except for sugar content which was over three times as high. Protein, although more nearly adequate than in the deer milk substitutes used in our early experiments, was, nevertheless, below that of deer milk. Fat content was similar to that of deer milk except, presumably, near the end of lactation.

Weight records for the twin fawns of the doe that furnished the milk samples, were kept for comparison with those of the two artificially reared groups described above (Fig. 1). By chance their original condition was closely comparable, being of the same sex, and averaging 9.5 lb. at a known age of 1 week. None of the fawns, either in the artificially reared or naturally reared groups, were among the largest does raised here, either at the start or at the end of the experiment. At 6 months of age the evaporated-milk-fed deer averaged 14 lb. heavier than the ones on whole milk, and 2.5 lb. heavier than the naturally reared fawns.

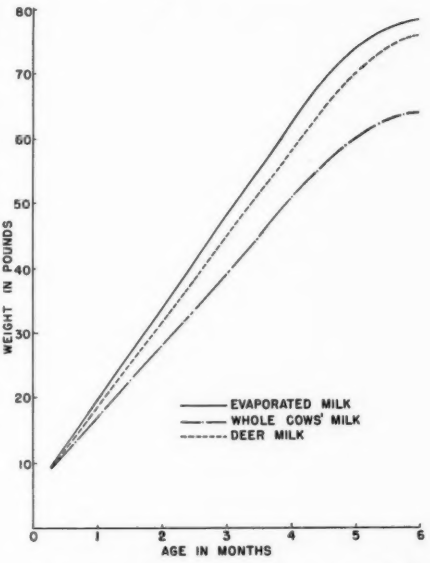

FIG. 1. Growth curve of naturally and artificially reared fawns.

A question which could not be answered without sacrificing the animals was whether the excess sugar and lower protein of the evaporated milk may have produced weight at the expense of some change in the normal ratio of fat to muscle.

Neither the evaporated-milk-fed nor naturally reared fawns suffered digestive upset or disease. The four on whole milk were subject to the usual digestive difficulties, which were controlled without medication by temporarily reducing the quantity and fat content of the milk, and heating it to just below the boiling point.

All fawns were allowed grain (sheep and goat ration) at will from the time they would eat it.

There was no observable difference in condition between fawns fed evaporated milk and those which nursed their dam. Both groups were noticeably healthier, larger and sleeker than the fawns on whole milk. All animals, with the exception of one in the whole milk group, came in heat and

TABLE 3.—COMPARATIVE EFFICIENCY OF WHOLE RAW MILK AND UNDILUTED EVAPORATED MILK AS FAWN RATIONS

	Whole Raw Milk	Evaporated Milk
Total consumption per fawn	300 lb. (150 qt.)	121 lb. (150 cans)
Approximate cost per fawn	$35	$21
Feedings per day		
June	5–4	4
July	4	3
August	3	2
September	2	–
October	2–0	–
Weaned	October 15	September 1

were theoretically capable of breeding their first year, although none was with a buck.

Cost of evaporated milk was 40 percent per fawn cheaper than whole milk (Table 3). Labor was greatly reduced as a result of the more rapid reduction in number of feedings per day, and earlier weaning. Less work was required in cleaning pens for the healthier deer. The need for mixing formulas was eliminated, and quantity purchasing and simpler storage requirements of the evaporated milk further increased efficiency. Natural rearing is, of course, less expensive than any artificial feeding program, but we have not found it practical to train naturally reared fawns, which are always wilder, for laboratory work.

CONCLUSIONS AND RECOMMENDATIONS

Undiluted evaporated milk is an efficient and readily obtainable food for artificial feeding of suckling fawns. It should produce animals comparable to those reared by their dams, and satisfactory for laboratory experiments. Its use is particularly recommended where economy or shortage of personnel prohibits compounding of special formulas.

SUMMARY

Experiments aimed at reducing production costs, and comparing growth of artificially and naturally reared fawns, suggest that large quantities of dilute formulas may overtax the capacity of the digestive system, resulting in digestive disturbances and retarded growth. Two fawns were raised on undiluted evaporated milk, two on their dam, and four on whole cows' milk. Those fed evaporated milk were slightly heavier than the fawns naturally reared, and 14 lb. heavier than the fawns on whole milk, at age 6 months. Cost of evaporated milk was 40 percent less than whole milk, and labor was reduced. Composition of evaporated milk, and does' and cows' milk at different stages of lactation is compared.

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EDGE TYPES AND ABUNDANCE OF BOBWHITES IN SOUTHERN ILLINOIS

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An abundance of edge, or ecotone where cover types meet, is widely believed to create conditions favorable for bobwhite quail (*Colinus virginianus*), but few quantitative data have demonstrated this. Conservationists have planted millions of multiflora roses (*Rosa multiflora*) under the assumption that, among other values, they would increase edge and thereby increase bobwhites. The objective of the present research was to test this belief.

The field observations were made during a 6-year period, 1948–54, within the Crab Orchard National Wildlife Refuge in Williamson County on land representative of the better bobwhite range in Illinois. Plantings of shrubs were made on an area of 3,500 a., and a nearby tract of 2,450 a. served as a control. Hunting was not permitted on either area.

W. N. Wandell established the project and supervised it during the period of active field work. Most of the data for the period June 1948 to May 1951, were collected by R. K. Stubbs, E. E. Filer, and H. D. Crawley; most of the data for the period from May 1951 to the end of 1954 were collected by R. J. Miller. Acknowledgment is made to the Branch of Wildlife Management Lands, U.S. Bureau of Sport Fisheries and Wildlife, for the opportunity to conduct the investigation on refuge land, for office space, and for other aids. Members of the Crab Orchard Field Trial Club helped with censuses of the bobwhites. T. G. Scott encouraged preparation of the manuscript and provided a final editing; R. E. Yeatter and C. O. Mohr, all of the Illinois Natural History Survey, furnished editorial assistance.

Methods

The bobwhites were censused mainly by trained personnel assigned to the project. Student assistants and members of the Field Trial Club aided, and all censuses were under close supervision. Two censuses were conducted per year, one in fall, mainly during the latter half of October, and one in winter, mainly around February 1. Whistling bobwhites were counted during late spring and early summer.

Dalke's (1941) techniques were employed in the preparation of cover maps. The length of ecotones on each quarter section during 1952 was determined from the maps. The number of bobwhites was then plotted against the number of miles of ecotone, and the coefficient of simple linear correlation was computed.

The length of edge present in 1952 was used in computations because lack of manpower hindered determining it for each year. Although some relations were thereby obscured, many were probably only slightly affected because, with two exceptions, cover types on most of the individual tracts either changed little or were nearly average in extent in 1952. In 1952, the amount of hayland was lower, and the amount of brushy grassland was larger than usual. Some tracts of brushy grassland in 1952 had too few bobwhites assigned to them because of previous occupancy of the tracts by hayland. Consequently, use of edge furnished by brushy grassland was somewhat underestimated and that furnished by hayland was somewhat overestimated.

Ten cover types (including roadsides) were recognized, mapped, and assigned symbols which were defined as follows: P1, pasture containing only a few shrubs and small trees; P2, pasture about half dominated by scattered clumps of brush and small trees; P3, pasture almost entirely dominated by small trees and dense brush; UF, forest, mainly on uplands; Cu, cultivated grain fields; H, hayfield and pasture

without brush; Rd, roadside; and F1, F2, and F3, fence rows containing, respectively, a sparse, medium, or dense growth of small trees and brush.

A cover tract was defined as a continuous area containing one kind of vegetative type. Ecotones were defined as the place where cover tracts met. For example, a 40-a. plot might have had corn in two outside strips and hayland in a middle strip. In this case, although there were only two cover types, there were three cover tracts. The average number of bobwhites per plot having only one cover tract, per plot having two cover tracts, etc., was computed. The coefficient of simple linear correlation for this relationship was then computed. The number of cover tracts is an indicator of the amount of ecotone.

DESCRIPTION OF RESEARCH AREAS

The Crab Orchard National Wildlife Refuge has a gently rolling topography and light-colored, infertile soils. The summers are hot and the winters mild. Snow falls frequently but melts quickly. The climate has been described by Page (1949).

The research areas and surrounding region were once forested but were cut over many years ago. Following the removal of timber, much of the land was cropped or pastured, chiefly by cattle. Later, certain fields were abandoned, and they reverted mainly to broomsedge (*Andropogon virginicus*), woody plants, and other old-field vegetation. The parts that are still wooded are dominated on upland sites by oaks (*Quercus* spp.) and hickories (*Carya* spp.), but numerous other species are present.

The land came under the control of the U.S. Bureau of Sport Fisheries and Wildlife in 1947; considerable cultivation was then resumed to provide food for wintering waterfowl. Most of the uncultivated land on the research areas continued to be pastured by cattle. In addition, the refuge and surrounding farmed areas became an important wintering ground for Canada geese (*Branta canadensis*). In spite of geese and cattle, land use proved favorable to bobwhites.

Cultivated fields occupied from 16.9 to 36.3 percent of the experimental area, but, in most years, the amount was about 28.0 percent. On the check area, the figures varied from 21.5 to 38.2 percent but were generally around 30.0 percent. During each year, forest and heavy brush covered about 29 percent of the experimental area and 20 percent of the check area. Brushy grassland increased as the study went on, and then declined to about 18 percent of each area, or nearly the same as at the beginning. The occupancy of hayland and non-brushy pasture declined somewhat, amounting to 17.4 percent on the experimental tract and 31.6 percent on the check area at the end of the study.

RESULTS

Amount of Edge

Linear miles of edge per sq. mi. averaged 20.89 on the experimental tract and 22.14 on the control tract (Table 1). The amount

TABLE 1.—LINEAR MILES OF PRINCIPAL KINDS OF EDGE PER SQUARE MILE OF RESEARCH AREAS IN 1952

Edge Type	Experimental Area	Check Area
UF–Cu	1.76	0.64
UF–H	0.15	0.21
UF–P1	0.30	0.72
UF–P2	0.75	0.59
UF–P3	0.87	0.29
P3–Cu	1.66	0.74
P3–H	0.05	0.27
P3–P1	0.10	0.50
P3–P2	0.37	0.46
P2–Cu	0.83	1.52
P2–H	0.04	0.51
P2–P1	0.12	0.71
P1–Cu	0.49	0.89
P1–H	0.19	0.47
H–Cu	0.57	0.22
F1	1.89	0.48
F2	3.74	2.18
F3	1.46	1.01
Miscellaneous	5.54	9.75
Total	20.89	22.14[1]

[1] A small error from rounding occurs in the third decimal place.

of each kind of edge differed considerably on the two tracts.

Multiflora rose and other shrubs were planted mainly in fencerows. They and the numerous naturally occurring shrubs and small trees are considered together in Table 1. Partly as a result of the experimental plantings, 1.89 linear mi. of fencerows with sparse brush (F1) were present per sq. mi. on the experimental area compared with 0.48 linear mi. on the check area. The corresponding figures for fencerows with moderate amounts of brush (F2) were 3.74 for the experimental area and 2.18 for the control area.

Edge between forest and cultivation (UF–Cu) was three times more on the experimental area than on the control area. Edge between pastures containing dense brush and cultivated grain fields (P3–Cu) also markedly exceeded that on the control area. On the other hand, edge between cultivated fields and pasture containing either moderate or sparse amounts of brush (P2–Cu or P1–Cu) was much more common on the check area than on the experimental area (Table 1).

Experimental Cover Plantings

Shrubs and trees were planted on the experimental area at locations where woody cover was scarcest, mainly between cultivated fields or between those and haylands or brushless pastures. Except for pine, most plantings were confined to fencerows, as previously mentioned. The kinds and amounts of plantings were as follows: Multiflora rose, 16.80 linear mi.; bicolor and sericea lespedeza (*Lespedeza bicolor* and *L. cuneata*), 4.25 linear mi.; miscellaneous, 4.25 linear mi.; loblolly pine and shortleaf pine (*Pinus taeda* and *P. echinata*), 14 plantations, each of 1 a.

Field work ended before the shrubs grew to optimum size, although after five growing seasons the shrubs were large enough to provide some useful cover. Sixty-one and one-tenth percent of the roses were at least 5 yr. old by the end of the study, and 34.4 percent were at least 6 yr. old.

Bobwhite Populations

For the 6-yr. period, an average of 199 birds per sq. mi. (1 bird per 3.2 a.) was present in fall on the experimental area, and an average of 170 per sq. mi. (1 bird per 3.9 a.) was present on the check area (Table 2), exceptionally high populations in the light of figures presented by Davison (1949:131–2). The highest number recorded per sq. mi. in fall was 245 on the experimental tract and 195 on the control tract.

The lowest population in winter during the 6 yr. of censusing was 117 birds per sq. mi. on the experimental area in 1952–53, and 80 birds per sq. mi. on the check area in 1953–54; averages for the entire period were, respectively, 137 and 104 birds per sq. mi., a fact which indicates unusual winter abundance also.

TABLE 2.—FALL POPULATIONS OF BOBWHITES, CENSUSED MOSTLY DURING THE LAST HALF OF OCTOBER

Year	Number of Individuals		Number of Coveys		Birds per Square Mile	
	Experimental Area	Check Area	Experimental Area	Check Area	Experimental Area	Check Area
1948[1]	961	375	74	31	176	98
1949	1,085	746	80	51	198	195
1950	882	649	68	65	161	170
1951	1,005	602	76	45	184	157
1952	1,334	665[2]	93	52[2]	245	174[2]
1953	1,136	508	93	40	208	152
1954	Down about 25%	Down 25–50%	—	—	—	—
Ann. avg.	1,088	634	82	51	199	170

[1] Figures for this year were too low because of insufficiently intensive censusing, and were not used in calculating averages.
[2] Calculated from a partial census (40.4 percent) of the check area.

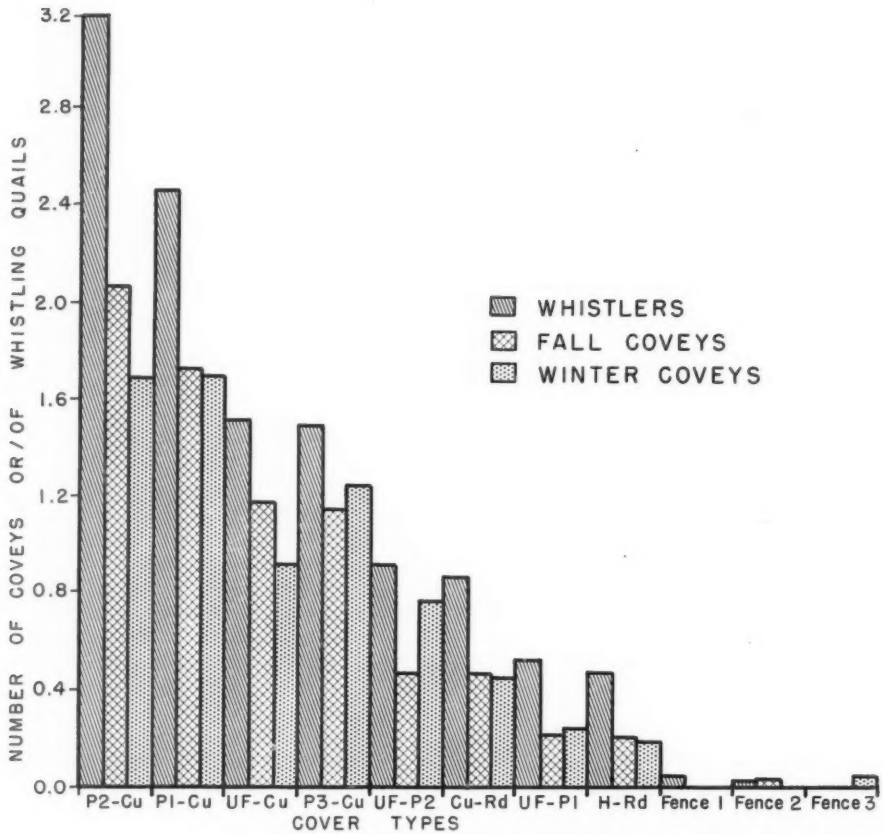

FIG. 1.—Average annual number of coveys and of whistling bobwhites per mi. of nearest kind of edge based on pooled data from both areas. (Edge types totalling 5 mi. or less not shown.)

Edge and Bobwhite Abundance

On the combined acreage of the research areas, the coveys and whistling birds were more often observed near cultivated fields than near other cover types (Fig. 1). Cultivated fields apparently were the principal source of food, a finding reported in many parts of the range of bobwhite quail. Edge between cultivated fields and pastures which contained sparse to medium amounts of brush (P1–Cu and P2–Cu) was intensively used (Fig. 1). Edge between pastures with various amounts of brush and cultivated fields (P1–Cu, P2–Cu, and P3–Cu) was more often used by coveys in winter than was that between cultivated fields and woodlands (UF–Cu). Coveys made somewhat greater use of forest-pasture edge in winter (UF–P1 and UF–P2) than they did in fall. Many edge types, particularly those involving non-woody pastures and haylands (H), received so little use that pertinent data are not shown in Fig. 1.

The amount of edge of all kinds and the number of bobwhites on each section and quarter section within the study areas were

also compared. In fall and again in winter there was a lack of significant correlation. The control tract had more ecotones (Table 1) but fewer birds (Table 2) per sq. mi. than the experimental tract had. Therefore, contrary to expectations, an increase in the general amount of edge did not lead to an increase in the number of bobwhites.

Cover types occurred in many combinations, some attractive to bobwhites and some not. The total of all kinds of edge could not be highly correlated with the number of bobwhites because the attractive edge types were in the minority.

The amounts of specific kinds of edge, in contrast to the total of all kinds, existing on the subdivisions of the study areas were next considered. These data were compared with the number of bobwhites observed nearby. Only one case of significant correlation was discovered. When the data for edge between cultivated fields and (1) sparsely brushy pastures (P1–Cu) and (2) moderately brushy pastures (P2–Cu) on the check area were pooled, they were significantly correlated with the number of coveys present in fall ($r = 0.973$; 14 d.f.).

Number of Cover Tracts and Bobwhite Abundance

On the 40-a. plots of the experimental area, the number of coveys in fall was rather closely correlated with the number of cover tracts present ($r = 0.981$; 6 d.f.).

Although 40-a. plots were smaller than desirable for this analysis, there was a mathematical reason for not choosing larger plots. Confidence limits are, to a considerable extent, determined by the square root of the number of sample items. Hence, with a limited acreage available, increasing the size of plots would have reduced their number. The average number of bobwhites per each given number of cover tracts would have become more variable.

Effect of Experimental Plantings

The establishment of 25 linear mi. of hedges and other plantings on an area of less than 5.5 sq. mi. amounted to intensive development. However, the plantings did not increase the population of bobwhite quail. Although at the end of the study the birds were more abundant on the planted area than they were on the check area, they were also more abundant on the planted area prior to its development (Table 2). The population of birds on the experimental area was lower in both February and fall than it was 5 yr. earlier. Populations on the undeveloped check area declined similarly. Records on bobwhites flushed throughout the investigation showed that the birds were rarely flushed near fencerows (Fig. 1) where most of the hedges were planted. If the birds were almost never seen there, the hedges, of course, could not have been effective. Planting additional fencerow cover on areas already supporting high bobwhite populations could hardly result in increased numbers of the birds, except possibly under very intensive and expensive management.

IMPLICATIONS FOR MANAGEMENT AND RESEARCH

Some unmentioned relationships were suggested by the data, but sample size was insufficient to demonstrate them. Many more quarter sections should have been sampled, and probably they should have been dispersed over a larger region rather than being placed in one solid block. It is becoming a truism that statisticians may prove more helpful before research begins than afterwards.

The work of game managers would be aided if they could readily identify some attribute of cover that permits rapid estimation of carrying capacity for bobwhite. The number of cover tracts per unit of area gave promise of being such a characteristic. It is easily determined, whereas determining the length of edge is highly laborious.

Our findings show that a rather small area of cultivation, about 30 percent of the total area in this case, will support numerous bobwhites providing that it is well

interspersed with other cover types. Establishment of small cultivated grain fields or food patches in predominantly wooded areas to produce the resulting desirable edge is often highly successful (Scott and Klimstra, 1954).

Edge containing lightly or moderately brushy pasture was used more than that containing forest or dense brush. This finding suggests that opening up or thinning out of forest and dense brush should receive considerable attention from game managers.

The present research indicates that bobwhites require more than one hedge of multiflora rose and receive little value from isolated plantings containing a single row of plants. Probably three or more hedges should be planted with no more than 100 to 200 yd. between each. Moreover, a group of hedges surrounded solely by large cultivated fields is, of course, inadequate for bobwhites and impractical for farmers. The hedges should be placed mostly in pastures or other areas containing grass, providing they are near cultivated fields. This will give many cover tracts within a small area. Numerous cover tracts per unit area indicate desirable conditions. Although management could create many cover tracts with only two cover types, the birds would not benefit. At least three kinds of cover must be represented: the royal triumvirate, ungrazed or moderately grazed grass, cultivated fields, and brush.

Perhaps attempts should be made to find or develop shrubs with better growth form than that of multiflora rose. Bobwhites may prefer woody cover as dense overhead as multiflora but more open underneath to facilitate visibility and movement. Although a more open spacing of multiflora rose would destroy its value as a living fence, the data suggest that such spacing might be desirable for bobwhites. Research in the southern Great Plains (Hanson, 1960) indicated that sand plum (*Prunus angustifolia*) would be suitable for cover development, partly because it has the proper growth form. Equally good shrubs can probably be found for other areas.

SUMMARY

The use of edge by bobwhite quail was investigated in southern Illinois from 1948 to 1954. Shrub plantings were made, but bobwhite populations did not increase, partly because the shrubs were planted in narrow strips, mainly near cultivated fields. Fencerows were the most common type of edge, but bobwhites seldom used such cover. Bobwhite populations were not correlated with the aggregate of all kinds of edge, because many of the kinds were not useful. Edge between brushy pastures and cultivated fields was the most used type. The number of cover tracts (or continuous areas containing one kind of cover) is easily counted and gives promise of being a good index to carrying capacity. Where hedges are needed, at least three should be established, about 100 to 200 yd. or less apart, on pastures or other areas containing ungrazed or moderately grazed grass near cultivated areas.

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NUTRITIONAL AND ACCEPTABILITY VALUES OF HARDWOOD SLASH AS WINTER DEER BROWSE

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Management plans for the white-tailed deer (*Odocoileus virginianus*) in Maine may include recommendations for habitat improvement, particularly in regard to winter food supplies. This investigation represents one segment of a long-term research effort aimed at providing a sound basis for such recommendations. The purpose of the study was to compare, in terms of nutrient and acceptability values, browse from the tops of three species of hardwoods felled at monthly intervals through the dormant season.

Previous studies have indicated that during dormancy twigs exhibit their highest nutrient content in the period immediately preceding leaf fall. At that time a portion of the nutrients within the leaves is transferred to the woody parts of the plant (Sampson and Samisch, 1935; Traub, 1927; Murneek and Logan, 1932). Seasonal variations in the nutrient content of various browse plants during dormancy have also been investigated. Hellmers (1940) reported that eight Pennsylvania browse plants ". . . exhibited trends indicating a reduction in nutritive value through the winter." Hundley (1959) found that protein and fat levels in five preferred Virginia browse plants increased during dormancy while nitrogen-free extract values tended to decline. Seasonal changes in the nutrient content of western browse species have also been studied by Bissell and Strong (1955), Hagen (1953), and Swank (1956), among others.

However, it was not known what, if any, changes might take place during the winter in the nutritive value of the tops following their cut at the period of peak food value. Furthermore, palatability of tops cut in the fall as compared to tops cut during the yarding season had not been previously investigated.

This study was administered jointly by the Maine Department of Inland Fisheries and Game, and the Maine Cooperative Wildlife Research Unit. (University of Maine, U. S. Fish and Wildlife Service, Wildlife Management Institute, and the Maine Department of Inland Fisheries and Game cooperating.) Financing was largely by funds from Pittman-Robertson Project W-37-R. Chester F. Banasiak, Maine Department of Inland Fisheries and Game, and Malcolm W. Coulter, Maine Cooperative Wildlife Research Unit, provided valuable guidance in the study and aided with the manuscript. Study sites were made available through the cooperation of personnel of the School of Forestry, University of Maine, and the Penobscot Experimental Forest, U. S. Forest Service. Proximate analysis was carried out by personnel of the Maine Agricultural Experiment Station. George C. Cooper and Bruce R. Poulton, University of Maine, assisted with physiological and nutritional evaluations, respectively.

Methods

Red maple (*Acer rubrum*), sugar maple (*A. saccharum*) and paper birch (*Betula papyrifera*), three deciduous species commonly involved in commercial operations in the vicinity of Maine deer yards, were selected for study. During two seasons, trees of these species were felled at monthly intervals from September through March. Twig samples for proximate analysis were collected from resultant slash. Cuttings were made in pole-stage, mixed hardwood stands on the Penobscot Experimental Forest in 1957–58 and on the University of

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Maine Forest in 1958–59. The cutting areas were grossly similar in terms of size, slope, soils, and species composition.

A continual comparison was obtained, through winter, of browse from trees cut at the period of known peak food value (months when leaves dessicate and fall) with browse from trees freshly cut during the time deer normally were yarding. Trees felled in September and October were sampled at the time of cutting and every month thereafter; trees cut monthly from November through March were sampled only at the time of cutting. In each season 54 samples, 18 per species, were collected.

Browse samples for proximate analysis consisted of 1 to 2 lb. of twigs cut to a maximum diameter of 3/16 in. Buds were included but all leaves and fruiting structures were removed. Upon delivery for analysis, generally within 24 hr. following collection, the twigs were weighed, oven-dried, and ground. A portion from each finely ground sample was measured and analyzed. Standard methods of the Association of Official Agricultural Chemists (1955) were used to determine moisture, crude protein, ether extract, crude fiber, ash, and nitrogen-free extract values. Fresh-weight values were calculated on the basis of moisture content of the twigs at the time they were collected.

Preferences of penned deer for various browse samples were determined through a series of nine acceptability trials carried out during late winter and early spring of 1958 and 1959. In both years, browse collected from trees felled in September and October, as well as from trees freshly cut, was offered to four animals in a 1½-a. enclosure. One wild adult doe and three hand-reared fawns were used in 1958. Dur-

TABLE 1.—AVERAGE COMPOSITION OF TWIGS COLLECTED FROM SEPTEMBER THROUGH MARCH

Source of Samples	Moisture	Percent Composition: Crude Protein	Ether Extract	Crude Fiber	Ash	Nitrogen-free Extract
RED MAPLE TWIGS			1957–58			
Trees cut in September	30.8[2]	4.7[1] 3.3	1.8 1.2	33.4 23.1	3.6 2.5	56.6 39.1
Trees cut in October	42.2	4.7 2.7	2.2 1.3	32.3 18.7	3.8 2.2	57.0 33.0
Fresh-cut trees November through March	46.8	4.7 2.5	2.0 1.1	32.0 17.0	3.6 1.9	57.8 30.7
			1958–59			
Trees cut in September	31.3	4.1 2.9	2.3 1.6	35.7 24.6	3.3 2.3	54.6 37.5
Trees cut in October	44.2	4.3 2.4	2.4 1.4	36.1 20.1	3.8 2.1	53.3 29.8
Fresh-cut trees November through March	46.7	4.2 2.2	2.4 1.3	35.3 18.8	3.8 2.0	54.4 29.0
SUGAR MAPLE TWIGS			1957–58			
Trees cut in September	31.7	4.3 3.0	1.3 0.9	40.6 27.8	4.0 2.8	50.1 34.0
Trees cut in October	39.1	4.6 2.6	1.5 0.9	38.0 21.6	4.2 2.4	51.7 29.5
Fresh-cut trees November through March	44.4	4.4 2.5	1.5 0.8	38.9 21.7	4.4 2.5	51.0 28.4

ing the following winter the captive deer included four fawns, three of which were hand-reared. Browse samples consisted of bundles of twigs, of the same species and the same cutting and collection dates, randomly arranged within easy reach of the deer. With the exception of one trial, samples were offered for periods of 24 to 48 hr. Following each trial the number of available twigs browsed was counted and the figures converted to percentages.

In an attempt to determine the relative nutritional value of the samples as reflected by weight changes in living animals, browse which had been dried and ground, was offered to albino rats with no conclusive results.

RESULTS

Nutrient Content

To simplify the following presentation, each of the three major categories of samples (September-cut, October-cut and fresh-cut) is subsequently referred to as a "sample group." On a moisture-free basis, which eliminate the obscuring effect of water content, proximate analysis at monthly intervals indicated only minor differences within and between the three sample groups. Table 1 presents a summary of those results. In general, fresh- and October-cut twigs averaged somewhat higher than September-cut samples in most nutrients. However, the differences appeared negligible. Furthermore, analysis of a series of samples collected on successive days indicated that errors involved in the sampling procedure were often of a greater magnitude than the small differences in composition between sample groups.

TABLE 1.—(CONT.) AVERAGE COMPOSITION OF TWIGS COLLECTED FROM SEPTEMBER THROUGH MARCH

Source of Samples	Percent Composition					
	Moisture	Crude Protein	Ether Extract	Crude Fiber	Ash	Nitrogen-free Extract
			1958–59			
Trees cut in September		3.7	1.2	44.1	3.0	48.0
	33.9	2.4	0.8	29.1	2.0	31.7
Trees cut in October		4.3	1.4	43.8	3.7	47.0
	43.3	2.4	0.8	24.8	2.1	26.6
Fresh-cut trees November through March		4.1	1.5	44.1	3.5	46.9
	44.3	2.3	0.8	24.6	2.0	26.1
PAPER BIRCH TWIGS			1957–58			
Trees cut in September		5.7	6.0	30.2	2.5	55.6
	36.3	3.6	3.8	19.3	1.6	35.4
Trees cut in October		6.0	6.6	29.1	2.3	56.0
	44.7	3.3	3.6	16.1	1.3	31.0
Fresh-cut trees November through March		6.0	6.3	28.9	2.4	56.4
	44.2	3.4	3.5	16.1	1.3	31.5
			1958–59			
Trees cut in September		5.5	5.5	32.0	2.1	54.9
	37.0	3.4	3.5	20.2	1.3	34.5
Trees cut in October		5.9	5.3	33.4	2.0	53.4
	46.4	3.2	2.8	17.9	1.1	28.6
Fresh-cut trees November through March		5.9	5.1	33.0	2.4	53.6
	45.7	3.2	2.8	17.9	1.3	29.1

[1] Upper lines of data show results on a moisture-free basis.
[2] Lower lines of data show results on a fresh-weight basis.

Preferences of Penned Deer

Browse collected from trees cut in September was less acceptable in late winter than that of fresh- or October-cut trees (Table 2). Preferences were more pronounced in the results of the first year's trials when the animals were more selective in their use of the samples, probably because of the greater amount of natural forage within the pen. In both years paper birch and red maple were preferred to sugar maple.

DISCUSSION

Differences in the composition of twigs of the three sample groups, on a moisture-free basis, were very small. Based upon proximate analysis, therefore, time of cutting did not appreciably influence the nutrient value of hardwood slash as winter browse. However, the preference of penned deer for browse from fresh- and October-cut trees was decided. This indicates that some difference in the nature of the twigs on a sample group basis did exist. The results of analysis on a fresh-weight basis were used to determine the existence of any relationship between the composition of the samples and their acceptability for two reasons: (1) moisture is known to influence the acceptability of foods for ruminants (Morrison, 1948), and (2) the acceptability of a food is more likely related to the food as it exists; that is, its original or fresh-weight composition.

On a fresh-weight basis, September-cut twigs contained considerably less moisture than samples from fresh- or October-cut trees (Table 1). Further, September-cut twigs averaged higher in relative amounts of most other constituents, especially crude fiber and nitrogen-free extract. Thus, a direct relationship between acceptability and moisture content and an inverse relationship between acceptability and relative fiber content existed.

Variations in the use of the samples on a species basis also suggested that succulence (a property determined by relative moisture and fiber quantities) was a major factor influencing acceptability. Paper birch, the most preferred browse, was lowest in fiber while sugar maple, the least preferred, was highest in fiber content. In addition, the margin between the three species in terms of both acceptability and fiber content was similar. Red maple twigs contained somewhat more fiber than paper birch but considerably less than sugar maple; differences in acceptability were also noticeably greater between sugar maple and red maple than between the latter and paper birch.

It is not suggested that relative moisture and fiber values would have necessarily ex-

TABLE 2.—BROWSING PERCENTAGES OF TWIGS OFFERED TO PENNED DEER ACCORDING TO TIME BROWSE WAS CUT

Year	Date Samples Offered	SEPTEMBER-CUT TREES		OCTOBER-CUT TREES		FRESH-CUT TREES	
		Number of Twigs in Sample	Percent Browsed	Number of Twigs in Sample	Percent Browsed	Number of Twigs in Sample	Percent Browsed
1958	Feb. 26	248	18.6	256	49.2	242	31.4
	Mar. 30	332	3.3	292	33.9	393	47.8
	Apr. 10	278	9.0	204	40.2	180	46.7
	Total	858	9.6	752	40.8	815	42.7
1959	Jan. 17	281	69.0	406	72.9	626	59.4
	Jan. 25	595	55.6	653	70.4	—	—
	Feb. 5	518	20.1	652	38.3	708	28.0
	Feb. 27	499	59.5	330	78.5	—	—
	Mar. 5	546	46.1	462	58.0	682	65.7
	Mar. 27	700	38.3	520	51.9	820	65.5
	Total	3,839	44.7	3,023	59.6	2,836	54.8

erted such an apparently marked influence on utilization of the samples under more natural conditions. The penned deer were receiving a commercial ration of four parts mixed grain and one part alfalfa pellets. This was believed to be complete in both its composition and the amounts offered. However, the importance of succulence as a determinant of the acceptability of foods for domestic ruminants is well known (Morrison, 1948). There is no reason to believe that succulence does not similarly influence acceptability of a forage for wild ruminants as well.

Factors relating to leaf fall appear to be pertinent in attempting to explain the difference in succulence between twigs of tops cut in September and those collected from fresh- or October-cut trees.

At the time of the September cuttings virtually all leaves were still present on the trees; a large majority of these persisted on the severed tops throughout the winter. By the time of the October cuttings, however, virtually all leaves had dropped. The presence of leaves on September-cut tops was the only visible difference between slash of the three sample groups. Leaves adhering to slash of September-cut trees possibly facilitated a loss of moisture from the twigs. Twigs from September-cut trees showed a seasonal decrease in moisture especially marked in the initial months following cut; no such pattern was reflected in moisture content of twigs from fresh- or October-cut trees.

Morrison (1948) states that well-liked foods are probably digested somewhat better than those which are equally nutritious, but less palatable. He also notes that ". . . livestock will usually yield the maximum amount of product on rations made up entirely or chiefly of palatable foods." Since differences in nutrient content on a moisture-free basis were negligible, acceptability is believed to be the most important factor in evaluating the samples used in this study. On that basis, slash from red maple, sugar maple, and paper birch trees felled after leaf fall provided more valuable winter browse than that of trees cut immediately before the leaves had dropped.

SUMMARY

Nutrient and acceptability values of browse from slash of three species of hardwoods felled at monthly intervals through dormancy were studied. Nutrient content differed little between twigs from trees felled during leaf fall and trees freshly-cut during winter. However, penned deer consistently preferred browse from fresh- or October-cut trees to that from trees cut in September. The more acceptable twigs were characterized by their greater succulence. The results indicate that trees felled any time after leaf fall provided browse that was equally as nutritious and decidedly more acceptable than browse from trees cut immediately before leaf fall.

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THE WILDLIFE SOCIETY

Minutes of the Wildlife Society Council Meeting, September 14, 1960

The Council met September 14, 1960, in the Denver-Hilton Hotel, Denver, Colorado. The meeting was called to order by President E. L. Cheatum at 9:30 a.m. Members present were Vice-president Jack N. Berryman and Regional Representatives Bill T. Crawford, Leonard E. Foote (alternate for Leslie Glasgow), Howard R. Leach, Lee Yeager, and R. J. Smith (alternate for Wendell Swank). Others present as observers or advisors were Tom Evans, Editor of *The Wildlife News*; past Executive Secretary J. P. Linduska; R. E. Johnson, representing The American Fisheries Society; Caleb Glazener, and the Executive Secretary.

Past Executive Secretary Linduska was asked to report on Society affairs since the last Council meeting. He reviewed the results of balloting by the members on the proposed Bylaws revisions, in which all proposals except that for raising membership dues carried by substantial majorities. The dues increase failed by a small majority. The balloting on this question elicited an unusual number of comments from the members, both pro and con.

Membership in the Society stands between 2,900 and 3,000. The financial condition is normal for this time of year, with reserves carried in savings accounts at interest.

Mr. Evans reported on *The Wildlife Society News* and was complimented on its improved format. He advised that the increased costs of the six-page issues require a corresponding increase in the amount budgeted for the printing of the *News*.

On a motion by Berryman, seconded by Yeager, the Council approved an increase in the budget to cover the cost of printing the six-page *News*. There followed a discussion of other minor increases in costs relating to publications and mailing. Upon a motion by Crawford, seconded by Berryman, the Executive Secretary was authorized by a unanimous vote to increase the Contingency Fund from $600 to $1,600 to cover the increased costs of publishing the *News* and to provide for other miscellaneous increased operating costs of the Society.

Following a discussion of the need for an attractive and comprehensive brochure or leaflet describing the Society's purposes and activities, Berryman moved and Crawford seconded a motion that the President appoint a committee to prepare a document of this type for consideration. The motion was carried.

The status and operations of the Employment and Professional Standards Committee were discussed. The manuscript, "Training and Employment of Wildlife Biologists and Fisheries Biologists" prepared by C. M. Kirkpatrick is receiving review by J. J. Hickey. It was agreed that the manuscript as it now stands is not considered to be an official policy statement of the Society, but is a useful contribution on the subject. It was further agreed that if a statement to this effect is included, Kirkpatrick's paper is appropriate for publication as a statement of the Committee without further review by members of the Council.

A detailed discussion followed on the question of adequately financing the Society's program in the light of the results of the balloting on the dues increase proposal. Alternative means of increasing income were considered. It was concluded that an increase in dues was required if the Society were to continue to grow and maintain the level of services now provided. This could be accomplished by a dues increase to $10. Further discussion revealed that the Council members were in agreement that the membership should be asked to reconsider the proposal that annual dues be increased to $15. This would permit the employment of a full-time executive secretary, the expansion of services, enhance the effectiveness of the Society's program, and be consistent with the amendments to the Bylaws which were adopted by the membership.

It was moved by Berryman and seconded by Yeager that prior to the annual meeting in March 1961, the members be requested to consider by ballot a proposal to increase the dues to $10 in order to maintain present services or, as an alternative, to increase the annual dues to $15 to strengthen the Society's program, with the results of the balloting to be announced at the annual meeting in March. Student member dues would remain at $6 as already approved by the membership. The motion was carried unanimously. (By a mail vote requested by President Cheatum on November 28, 1960, the Council by majority action approved the submission to the membership of an additional Bylaws amendment proposal which would increase Life Membership payments from $100 to $200 effective January 1, 1961. This action would be required to safeguard the financial welfare of the Society.)

Vice-president Berryman was appointed chairman of a committee to draft a full statement explaining the proposals to the membership and to prepare the ballot. President Cheatum urged all Council members to cooperate by submitting their views to the chairman and requested the Regional Representatives to prepare letters to their respective constituents urging full and earnest consideration of the proposals. Material for inclusion in the November *News* must be received by Editor Evans by October 20. The ballots would have to be in the hands of the members no later than January 25.

After consideration of other means of increasing revenues, a motion was made by Yeager and seconded by Berryman that the policy of the Society to withhold the membership mailing list from sale to commercial users be continued. The motion was carried unanimously. It was agreed that interest and dividend accruals on investments should be added to the investments, as is currently practiced, and no action on this matter was required. No

action was taken on a suggestion that members be required to pay publication return and remailing charges when they fail to give prior notice of change of address.

The President reported that he had completed all committee appointments, and that Russell De Garmo had been appointed to replace Roger Latham, who had asked to be relieved as Regional Representative in Region I, in accordance with provisions of the Bylaws.

Reports were read which had been received from the following:

J. P. Linduska, Representative to the Waterfowl Advisory Committee.

James T. McBroom, Representative to the National Watershed Council.

Hoyes Lloyd, Representative to the International Council for Bird Preservation.

It was moved by Berryman, seconded by Foote, that these reports be condensed, if necessary, and published in the *News* with the authors' consent. The motion was carried.

Consideration was given to proposals for additional Bylaws revisions submitted by Gustav Swanson, Chairman of the Constitution and Bylaws Committee. Comments by individual members of the Committee also were considered. Recommendations concerning dues increases had previously been acted upon as noted above. With respect to special provisions for a foreign member class, Yeager moved, with a second by Crawford, that this matter be tabled pending action by the membership on the annual dues question. The motion carried.

A further recommendation by the Committee on the formation of state chapters was considered. A motion was made by Smith, seconded by Crawford, that the Council endorse the principle of establishing state chapters, subject to the same regulations respecting membership and voting privileges as apply to sections, and that the Constitution and Bylaws Committee be requested to prepare model bylaws for such chapters and to prepare a Bylaws amendment proposal for publication in the February 1961 *News* preparatory to requesting action on the proposal at the annual meeting in March. The motion was carried unanimously.

The President reported on the work of the Committee on Organizational Cooperation in the absence of members of that committee. Exchanges of correspondence and talks with the members of the corresponding committee in the American Fisheries Society had not as yet provided a firm basis for definite recommendations. This matter should be studied further and opportunities would be sought to discuss possibilities with representatives of the American Fisheries Society at the Midwest Wildlife Conference in Toronto in December. The Executive Secretary was directed to discuss possibilities of cooperation in the establishment of a joint office in the Washington, D. C., area, for handling clerical and routine administrative functions of both societies, with the Secretary-Treasurer of the American Fisheries Society. The results of all further studies will be reported to the Council.

Plans for a membership drive have been held in abeyance pending decisions on the dues proposals. Chairman Swank will now organize and carry out the drive on the basis of the actions taken so far.

The President advised that he would explore the possibility of the Society's obtaining representation on the U.S.D.A. study on reclassification of positions in the fish and wildlife field.

The President reported having received support of the negative views expressed in his memo of June 8, 1960 to the Council on the establishment of a committee to consider the use of radio transmitters or other electronic devices on animals. It was agreed that the establishment of committees on matters of this kind would tend toward the undue proliferation of committees in the Society's structure. As an alternative he made two additional appointments (Lowell Adams and Frank Craighead) to the Manual of Wildlife Techniques Committee to study this subject.

Mr. Smith reported on proposed recommendations by the Wildlife Conservation and Planning Committee of the International Association of Game, Fish and Conservation Commissioners which the Chairman had submitted to the Society for review. It was moved by Berryman, seconded by Yeager, that the Council endorse the proposed report and its recommendations for strengthening the internal operations of the IAGFCC. The motion was carried.

For the purpose of the record and in order to meet requirements of certain banks in connection with the transfer of accounts, the appointment of C. Gordon Fredine as Executive Secretary was confirmed by the Council. Upon his recommendation the Bank of Bethesda, Bethesda, Maryland, was designated to receive the checking account of the Society. The actual transfer of records of the Society and other responsibilities of the Executive Secretary was accomplished on August 31, 1960. Executive Secretary Fredine pointed out that the Bylaws provide no alternative administrator of the Society's funds and records, short of the appointment of a replacement, should the Executive Secretary be incapacitated. He was requested to refer this matter to the Bylaws Committee for consideration.

Recognition was given to the efficient, faithful, and generous manner in which Joseph P. Linduska had carried out the duties of the Executive Secretary for the past three years. It was moved by Yeager, seconded by Foote, that Linduska be given a Life Membership in the Society in partial recognition of his outstanding service. The motion was carried unanimously.

There being no further business, a motion for adjournment was seconded and passed. President Cheatum declared the meeting adjourned at 4:45 p.m.—Respectfully submitted, C. GORDON FREDINE, Executive Secretary.

BRIEFER ARTICLES

AGE CLASSIFICATION OF THE CHUKAR PARTRIDGE

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There are many methods for distinguishing young from adult in gallinaceous birds. Inspection of the bursa is reliable for most species but must be done in the field by trained personnel. However, when peculiarities of the wing can be used as criteria, wings can be collected rapidly, in large numbers, and on a statewide basis.

Distinctive features of the post-juvenile molt have been used successfully to determine age in gallinaceous birds. Various species of partridge and quail retain the outer two juvenile primaries until the first post-nuptial molt. These juvenile primaries can usually be distinguished by their shape and color from the corresponding adult primaries. When wings are collected early in the fall, the stage of molt with respect to these outer two primaries often distinguishes adult from young. Leopold (1939) distinguished juvenile bobwhite quail (*Colinus virginianus*) by the presence of the outer two juvenile primaries and white- or buff-tipped greater primary coverts; adult coverts are slate-grey. Wallmo (1956) developed a similar method for distinguishing juvenile scaled quail (*Callipepla squamata*). In a bird of the year the outer two primary coverts are plain grey, while the rest are tipped, edged, or mottled with white or tan. Scaled quail retain these coverts during the post-juvenile molt but replace them during the first post-nuptial molt by solid grey adult coverts.

To the chukar (*Alectoris graeca*), I have adapted a procedure developed by Eng (1955) on the sage grouse (*Centrocercus urophasianus*). This method is particularly useful in that it applies from August to late November.

Acknowledgment

This paper is an extraction of a master's thesis by the author completed in 1958 at Utah State University. For advice and criticism during this study, I am especially indebted to Allen W. Stokes, Utah State University. The study was conducted with the cooperation of the Utah Cooperative Wildlife Research Unit and the Poultry Husbandry Department, Utah State University.

Methods

Approximately 130 chukar wings were studied. Through the cooperation of the Utah State Department of Fish and Game, 50 wings from known-age, banded chukars were obtained during the November 1956 hunt. Another group of 82 wings was collected on September 22, 1957, at a checking station near Reno, Nevada, for which I am indebted to Glen C. Christensen of the Nevada Fish and Game Commission. Age was verified by bursal examination and the presence of mottled juvenile secondaries. Galbreath and Moreland (1953) used the mottling of the more proximal juvenile secondaries to distinguish young of the year from adults during August and September. In studying 94 captive juvenile chukars during 1957, I found none had retained these mottled secondaries beyond the 17th week.

Results

The procedure for aging juvenile chukars is based on certain characteristics of the post-juvenile molt.

Mottled juvenile secondaries.—Until the young chukars are around 15 weeks old, they retain a few mottled secondaries, although absence of these does does not necessarily indicate an adult.

If the mottled secondaries are not present, the primary which has been replaced most recently is determined. When the primaries are numbered consecutively from the bend of the wing to the tip, the wing may be placed in one of the following five categories:

Primaries 10, 9, and 8 not molted.—The bird is probably a juvenile if these three primaries are gradually tapered to a point. In a typical juvenile, the eighth flight feather (Fig. 1A) has a distinctly mottled leading edge. In an adult, the eighth primary would have a solid yellow marking on its leading edge and would be more rounded at its extremity. No adult wings were collected that could be placed in this category.

Primaries 10 and 9 not molted.—If the two unmolted primaries have a gradual taper to a fairly sharp point and are only barely faded in comparison with the adjacent adult primaries, the bird is a juvenile. There will probably be one or two mottled secondaries remaining on the elbow that may be obscured by the greater secondary coverts.

Fig. 1B shows primaries 10 and 9 sharply pointed and gradually tapered. The emerging eighth primary is about 2 cm. long. On this basis alone we would have to place this bird in the juvenile class. The outer two primaries on this wing, however, were ragged and badly faded. This condition indicated a 1-year-old bird which had not yet molted these last remnants of its juvenile plumage, or rarely, an adult which had retained abnormally the juvenile primaries through the post-nuptial molt.

If, on the other hand, the outer two primaries

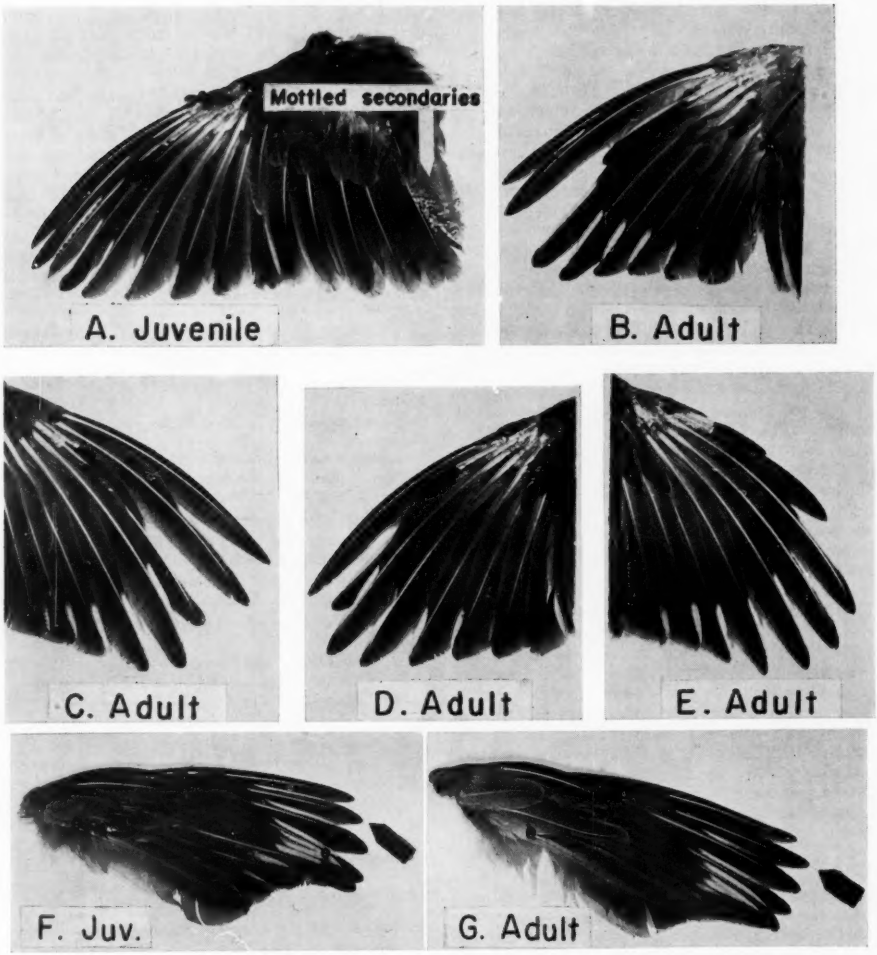

FIG. 1. Adult and juvenile chukar wings in various stages of molt.

have more rounded tips and are uniformly but only slightly faded, the bird is an adult (Fig. 1C).

Primary 10 not molted.—In the great majority of cases, if the ninth primary has been molted the chukar is an adult (Fig. 1D). Nevertheless, in a group of 25 captive chukars hatched May 31, 1957, I observed 4 which had molted the ninth primary the first year. Thompson and Kabat (1950) report a similar molting of the ninth primary in juvenile bobwhite quail and suggest date of hatching or environmental factors as the probable cause.

Primary 10 just molted and new feather growing in.—In this case the bird must be an adult (Fig. 1E).

Molt complete; all primaries fully grown.—If hunting is late enough in the season, molt in both adults and juveniles may have progressed to the point where the above characters are useless. Close examination of a juvenile wing shows the ninth primary faded when compared with the adjacent adult eighth primary. The corresponding feathers on an adult wing show no such variation in coloring (Fig. 1G). Furthermore, the ninth primary

of the juvenile is considerably shorter than the eighth primary (Fig. 1F). Of the wings collected during the 1956 Utah chukar season, 18 were juveniles. In this group the ninth primaries ranged from 5 to 9 mm. shorter than the eighth. In only 3 of 21 adult wings examined was the ninth primary more than 2 mm. shorter than the eighth. Also, the outer two juvenile primaries are gradually tapered to a point. The corresponding adult primaries are more rounded at their tips.

SOURCES OF BIAS

One factor that tends to reduce the accuracy of this aging method for chukars is that some early-hatched chukars undergo an extension of their normal molt and lose the ninth primary the first year. The aging method described here would erroneously classify such a juvenile wing as adult. Juvenile wings with an extended molt probably will be collected only during a late hunting season. If the hunting season is early, molt of young chukars will not have progressed to the ninth primary even among early-hatched birds. However, during the Utah hunt of November 1956, 6 of the 18 juvenile wings collected had lost the ninth primary. If the ninth primary were molted in a comparable percentage of a random group of juvenile wings, the use of the aging technique would be questionable indeed, at least during a late hunting season. Banding records show that 15 of these 18 wings were from birds hatched about May 27 and 24 weeks old when collected. Since the peak of hatch in wild chukars in the same area is between the first and second week of June, the collected wings were from an early hatch. This fact probably accounts in part for the extended molt. Among a group of 14 captive chukars hatched June 26, 1957, none had molted the ninth juvenile primary by mid-November. The extent of the extended molt bias is not known, but is probably negligible if confined to early-hatched birds.

TEST OF AGING TECHNIQUE

To verify the validity of the technique just outlined, three students aged a group of chukar wings after a brief explanation of the method. For the test, 25 wings from the birds collected during the September hunt in Nevada were used. The wings collected during this hunt were from a random group of wild-reared chukars. Approximately equal numbers of adults and juveniles, however, made up the 25 test wings. An additional 25 wings from game farm chukars, banded, released, and shot during the November season in Utah, were tested at the same time, bringing the total to 50 wings. Most of the 13 juvenile wings in the game farm group were from birds of the same age hatched about May 27. About 30 percent of these, probably because May 27 was an early hatching date, had lost the ninth primary. Anyone using the aging technique described here would have aged these wings as adults. Extended molt bias does exist in any sample but is probably not of the magnitude of this sample. The inclusion of these wings in the test would have suggested a larger number of incorrectly aged birds than would occur in a random group of wings from wild-reared chukars. When the juvenile wings missing the ninth primary were replaced by ones having the ninth juvenile primary present, two of the men taking the test aged all of the wings correctly, the other misjudged only one.

SUMMARY

The technique for separating adults and juveniles by examination of the wings is summarized as follows:

Mottled secondaries on elbow.—This condition positively identifies a juvenile.

Mottled secondaries absent.—The bird may be adult or juvenile. Reference to the stage of molt will place the bird in one of the following categories:

1. Primaries 10, 9, and 8 not molted
   - Leading edge of eighth mottled; pointed tip; faded ..... JUVENILE
   - Leading edge of eighth has even yellow marking; and rounded tip ..... ADULT
2. Primaries 10 and 9 not molted, primary 8 just growing in.
   - Primaries 10 and 9 gradually tapered with pointed tips, only slightly faded ..... JUVENILE
   - Primaries 10 and 9 with more rounded tips; may be only slightly faded ..... ADULT
3. Primaries 9 and/or 10 molted, new primary growing in ..... ADULT
4. Molt complete, all primaries fully grown
   - Prmary 9 faded and at least 5 mm. shorter than primary 8; pointed tip ..... JUVENILE
   - Primary 9 not faded and almost equal in length to primary 8; more rounded tip ..... ADULT

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WEATHER INFLUENCES ON THE ONSET OF BREEDING IN MISSOURI COTTONTAILS

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The purpose of this paper is to report the effect on breeding in Missouri cottontails of a period of abnormally high snowfall and prolonged cold in February and March of 1960.

In most years, central Missouri cottontails (*Sylvilagus floridanus*) begin breeding about the end of February. Schwartz's (1942) data for 1939 and 1940 showed first conception dates about March 1, and our own data for 1958 and 1959 show a median first conception date of February 26. The uniformity of the onset of breeding in these 4 years suggests a photoperiod effect governing the onset of breeding. Lyman (1943) demonstrated that altering the duration of illumination may modify greatly both the sexual and molting cycle in the varying hare. Bissonette (1938) and Bisson-

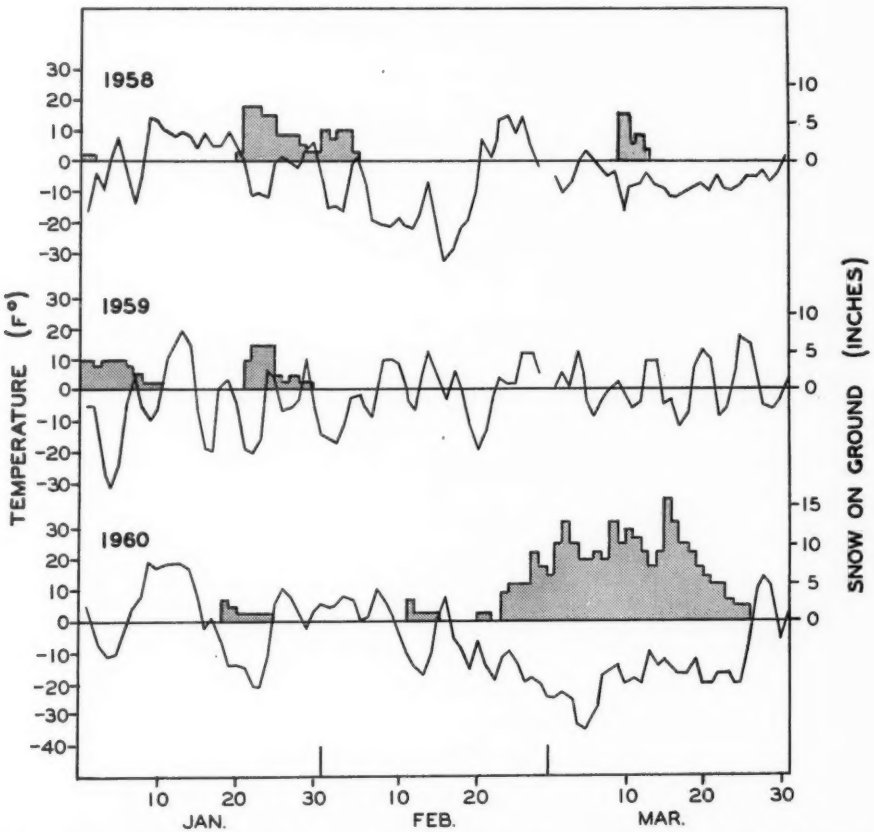

FIG. 1. Snow depths and average daily temperatures at Columbia for January, February, and March, 1958 through 1960. Temperatures are represented by an irregular solid line and expressed as deviations from daily norms indicated by the straight lines. Snow depths are represented by the stippled bar graphs.

ette and Csech (1939) demonstrated modifications in the timing of the sexual cycle of cottontails by alterations of photoperiod.

Our data indicate that although photoperiod may be the basic mechanism controlling the timing of the sexual cycle in the cottontail rabbit, severe weather can strongly influence the onset of breeding. Delayed breeding because of weather was suggested by Hamilton (1940). He stated that first mating of cottontails in New York usually occurs in late February or early March, but inclement weather or some other factor may delay it until late March. No data accompanied this statement of possible delay.

METHODS

The animals studied were wild rabbits collected in late winter and early spring in 1958, 1959, and 1960. Most were collected within a 20-mi. radius of Columbia in central Missouri (Boone County). One group was taken in 1960 on the James A. Reed Wildlife Area near Kansas City, Missouri. Rabbits collected were weighed, aged, and sexed, and reproductive tracts removed and preserved in A.F.A. The numbers of embryos, corpora lutea, and resorptions were recorded. All conception dates refer to first pregnancies of individuals for the season and were determined from growth data developed by Schwartz (1942) on the crown-rump measurements of embryos.

Weather records used in this study represent observations of the U.S. Weather Bureau Station at Columbia.

WEATHER RECORDS

A series of severe snowstorms began on February 23, 1960. Days with more than 1 in. of snow falling were February 23, 25, 27 and 28, and March 2, 6, 8, 10, 14, 15, with lesser amounts falling each day thereafter until the 19th. Snow remained on the ground until March 26 (Fig. 1). By comparison, only in 1958 did any snowfall occur during March. Snow fell on the 9th and melted by the 12th.

Temperature data in Fig. 1 represent deviations from daily norms. During 1960, in a 39-day period from February 17 to March 26, the temperatures averaged 16 degrees below normal. The lowest temperature of –9° F. occurred on March 5 and was 35° below normal for that date. In 1959,

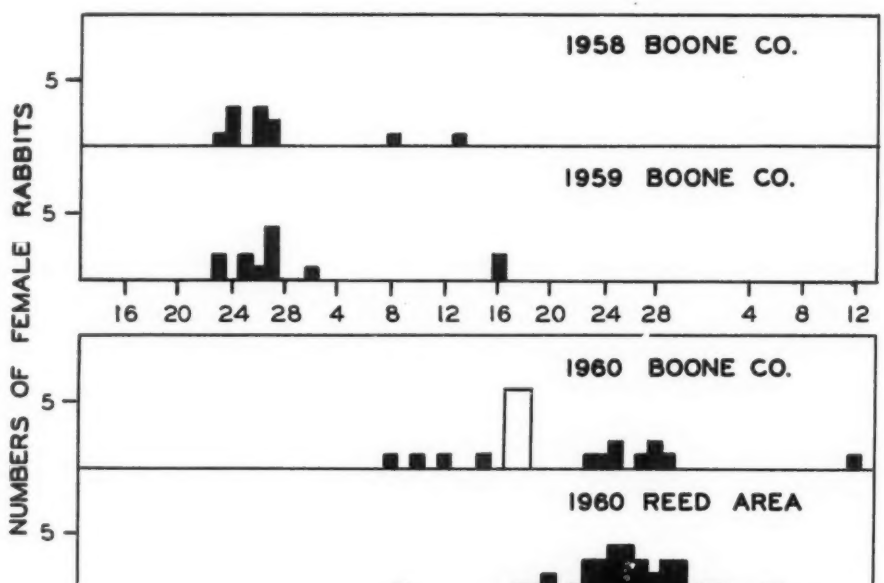

FIG. 2. Conception dates for first pregnancies are indicated by the solid bars. Open bars indicate non-pregnant females at the time of collection.

temperatures fluctuated above and below normal during February and March, while in 1958, March was slightly below the seasonal norms.

ONSET OF BREEDING

In both 1958 and 1959, back-dating from estimated ages of embryos from rabbits collected in Boone County demonstrated median conception dates of February 26 and 27, respectively (Fig. 2). In 1960, the median conception date was March 25. In a collection of 14 rabbits made on March 19 and 20, 12 females were not yet pregnant. This collection of non-pregnant females does not allow the computation of conception dates but it clearly demonstrates a delay in the onset of breeding. Non-breeding females were not taken in 1958 and 1959 after March 15 of those years.

A collection of 34 females was made on the James A. Reed Wildlife Area, 120 miles west of Columbia, in April 1960. This collection is not supported by similar collections from previous years. However, this collection also demonstrates a median conception date of March 25. The variation in first conception dates in the 1960 collections indicates that the earliest dates fell well after the median conception dates recorded for 1958 and 1959.

DISCUSSION

In view of the generally accepted hypothesis that lengthening photoperiod is the mechanism responsible for governing the onset of breeding in most mammals, it is important to record an observation of the influence of weather on this mechanism.

Since the gestation period of the cottontail is approximately 28 days (Hendrickson, 1943), the first litter normally expected in March was delayed until late April in 1960. Schwartz (1942) computes an average of about four litters per year for Missouri cottontails, with the breeding season extending until the first week of September. He records six potential breeding periods, with some synchronization of conception dates demonstrated in the early portion of the breeding season. An increase in the pregnancy rates during late summer could compensate for a lack of March litters. Such compensation should be demonstrable in the age composition of the young in the fall and winter hunting seasons.

It is not suggested that abnormal weather is the basic mechanism of population control. These conditions occur only rarely in Missouri and do not coincide with the regular fluctuations in population density (Wight, 1959).

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NEW USE OF FUNNEL TRAP FOR RUFFED GROUSE BROODS

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A different method of taking broods of ruffed grouse (*Bonasa umbellus*) has been used successfully for a short period in spring in the mountains of North Carolina. Two hardware cloth cages, one 4- × 4- × 2-ft. with short funnels (1960. Manual of Game Investigational Techniques, Sect. 10:11) large enough to permit entry of the hen on each of two sides, and another cage 1- × 1- × 6-in. are needed. These can be transported easily in a pickup truck. Areas where broods are frequently seen are traveled until a brood is sighted and one or more young birds are captured. These are placed in the smaller cage in an open spot where caught. The funnel trap is placed over the cage, and covered with clear plastic to protect captured birds against showers. Normally, the nature of their habitat will prevent exposure to excessive sunshine. However, should there be danger of this, a few leafy tree branches on top will provide sufficient shade. Crying of the young will attract the hen and remainder of the brood to them. The hen often will not enter until just before dark. On some occasions, hens refusing to enter can be captured with a large hoop net.

The principal disadvantage in this method is that it can only be used during the short period between hatching and development of flight powers.

Received for publication March 21, 1960.

EPIPHYSEAL CARTILAGE AS AN AGE INDICATOR IN FOX AND GRAY SQUIRRELS[1]

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This paper reports the results of an investigation to determine the limiting dates applicable to aging fox and gray squirrels (*Sciurus niger* and *S. carolinensis*) by X-ray examination of the epiphyses of the lower foreleg. The technique is similar to that initially proposed for the cottontail (*Sylvilagus floridanus*) by Thomsen and Mortensen (1946), extended by Hale (1949) and applied to gray squirrels by Petrides (1951).

The writer wishes to express his gratitude to E. E. Good and E. H. Dustman for much advice and assistance throughout this study.

Methods

Experimental Animals

Nestlings of both species were reared artificially and X-rayed throughout the period of growth in order to determine the age at which the distal epiphyseal cartilage plates of the radius and ulna are replaced by bone. The 3 litters used in the study were estimated to have been from 38 to 42 days old when found, with birth dates set at March 7 to 13. All gray squirrels (four) were males, while the fox squirrels comprised two males and four females. Brown and Yeager (1945) and Uhlig (1955:58) have published criteria for aging nestling squirrels from birth to 8 weeks of age. With reference to these criteria, it is believed that ages assigned to the three litters are accurate to within 1 week of their actual ages. When the experimental animals were fully weaned, they were transferred from small indoor cages to a large outdoor cage measuring 16 × 10 × 8 ft.

Radiography

The wrist area of the experimental animals was radiographed at intervals from the time they were 14 weeks old until consolidation of the epiphyses and diaphyses occurred. During the early part of the study, one member of each litter was X-rayed every 2 weeks; litter members were rotated to reduce any hazard that might result from the procedure. Toward the end of the study, as the epiphyseal cartilage narrowed and disappeared, the squirrels were X-rayed weekly and more than one member of each litter was examined.

To obtain an X-ray plate of the foreleg of a squirrel, the animal was confined in a wire cone and anesthetized with ethyl ether. When the squirrel was sufficiently relaxed, two heavy rubber bands were looped around the wrist, and the foreleg was extended over an X-ray film. A portable X-ray machine and dental X-ray film (1¼ × 1¾ in.) were used.

Results

The distal epiphyseal cartilage of the radius and ulna has three rather distinct thicknesses during the longitudinal growth of these bones. During the early stage of bone growth (Fig. 1, upper left) the cartilage is at its maximum thickness, two-thirds of a millimeter or more, and is represented by a light line of this width between the epiphyses and diaphyses. During the intermediate stage of growth (Fig. 1, upper right) the cartilage is reduced to a thin disc having a width of about one-fourth of a millimeter. The cartilage is maintained at this thickness for several weeks. During the final stage of growth (Fig. 1, lower left), the epiphyseal cartilage is gradually reduced from the intermediate level and is replaced by bone as shown in Fig. 1, lower right.

The series of X-rays indicates that the transition from maximum to the intermediate cartilage thickness occurs in less than 14 days. Closer definition is not possible because the squirrels were X-rayed at 2-week intervals during the early part of the study. The transition is marked not only by reduced thickness of the cartilage, but also by definite capping of the epiphyses over their respective shafts. The cartilage is maintained at a rather constant width throughout the intermediate stage of growth. Reduction in cartilage thickness during the final phase of bone growth is very gradual. The characterisic stages of epiphyseal cartilage development at various ages are given in Table 1.

From the X-ray photographs, it is seen that the epiphysis is surrounded by a thin layer of compact bone. As revealed by X-ray examination of shot squirrels, the compact bone of the epiphysis adjacent to the diaphysis is present in some adults and absent in others. The usefulness of the aging technique would be enhanced if the age at which this compact bone disappears were known.

Discussion

The diet supplied the animals was adequate in nutrients known to affect bone growth and development. The vitamin D requirement was satisfied through exposure to direct and reflected sunlight.

Although it is known that a female squirrel can

[1] Contribution from the Ohio Cooperative Wildlife Research Unit: The Ohio State University, Ohio Division of Wildlife, U.S. Fish and Wildlife Service, and the Wildlife Management Institute cooperating.

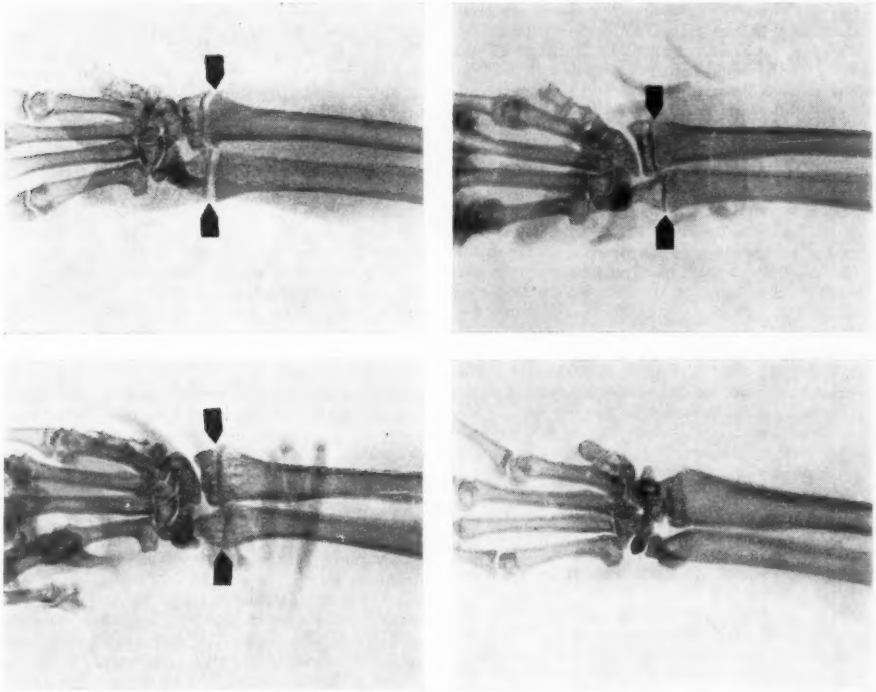

FIG. 1. Epiphyseal cartilage and bone growth of radius and ulna in gray and fox squirrels. *Upper left.*—Early phase. *Upper right.*—Intermediate phase. *Lower left.*—Final phase. *Lower right.*—Complete union of epiphyses and diaphyses. Magnification of bones about twice natural size.

bear young during the same breeding season in which it is born (Uhlig, 1955:41), the term "adult," as used in this paper, refers to animals that are not products of the most recent breeding season.

Chronological Limitations

Since most, if not all, eastern fox and gray squirrels are born from February through September (Allen, 1943; Brown and Yeager, 1945; Uhlig, 1955), a large collection of forelegs taken during the open hunting season may generally be expected to show all three conditions of the epiphyseal cartilage. The limiting dates for collection of forelegs for aging purposes are determined by the litters produced late in the breeding season of the preceding year, and by the litters produced early in the breeding season of the collection year. In case of fox squirrels, an overlap in ossification stages occurs during the latter half of June between the latest born young of the preceding year and the earliest born young of the present year. That is, forelegs representative of both groups collected at this time would all have the intermediate cartilage thickness and would be radiographically indistinguishable. Consequently, July 1 must be set as the earliest date for collecting forelegs.

The earliest young-of-the-year will have lost all cartilage by mid-January. The limiting dates for

TABLE 1.—AGE LIMITS FOR STAGES OF EPIPHYSEAL CARTILAGE DEVELOPMENT AS DETERMINED BY X-RAY

	Early Stage	Intermediate Stage	Final Stage
Gray Squirrels			
Male[1]	Birth to 18 weeks	19 weeks to 33 weeks	33 weeks to 46 weeks
Fox Squirrels			
Male	Birth to 18 weeks	19 weeks to 39 weeks	39 weeks to (54 weeks)[2]
Female	Birth to 18 weeks	19 weeks to 39 weeks	39 weeks to 50 weeks

[1] The experimental animals included no female gray squirrels. A sex difference in age at closure may exist.
[2] The study was terminated before epiphyseo-diaphyseal union occurred in the male fox squirrels. However, the cartilage had diminished in thickness to a point permitting an estimate of final closure to be made.

aging fox squirrel populations by the X-ray technique are therefore July 1 and January 15.

All fox squirrels having thin cartilage of the final growth stage before November 1 will be adult animals born the preceding year. Squirrels showing this condition after November 1 will be young-of-the-year.

The limiting dates for aging gray squirrel populations are somewhat different. The difference is due to the fact that the longitudinal growth of the radius and ulna is completed in less time in this species than is the case with fox squirrels. As indicated in Table 1, closure of epiphyses occurs earlier in female than in male fox squirrels; if this is true also of the gray squirrel, then the terminal date for this species is probably near the end of November rather than the second week in December.

The only overlap between adults and juveniles occurs during the first part of February. This overlap, however, is of no consequence because juveniles at this time would not be out of the den. The limiting dates for aging gray squirrel populations by the epiphyseal cartilage are, therefore, February 1 and December 1.

Any gray squirrels showing the final cartilage width before the latter part of September will be adults born the preceding year. Similarly, any squirrels having the intermediate cartilage width before the second week in June will have been born the preceding year.

Since relatively few fox or gray squirrels are born as early as February, the terminal dates for both species could be extended several days without impairing the reliability of the aging technique.

Because the maximum cartilage width persists in fox and gray squirrels until they are 18 weeks old, it is possible to separate the forelegs of spring-born and summer-born juveniles by means of X-ray pictures. If, for example, the forelegs are collected on October 1, those from most squirrels born after the first of June will have maximum thickness of epiphyseal cartilage; juveniles born before this date will have intermediate cartilage thickness. Gray squirrels born in early February will show final cartilage width by October 1.

The dates given in the preceding paragraphs are subject to some error because the experimental animals could not be aged precisely when found, and because the X-rays were taken at 1- and 2-week intervals. A further point to be recognized is the matter of variability in animals.

Age at Sexual Maturity

Recent studies of the male squirrel reproductive tract (Kirkpatrick, 1955; Mossman, *et al.*, 1955; Hoffman and Kirkpatrick, 1956) have increased our knowledge of sexual development and more clearly defined the extent of error inherent in assigning squirrels to age classes on the basis of external characters. Kirkpatrick and Barnett (1957), in comparing skeletal characteristics with the histological condition of testes and accessory glands of gray squirrels, found a correlation to exist between the stage of sexual development and the degree of ossification in clean, dry humeri and femora. The bones were classified as ossified or unossified with reference to the absence or presence of a notch on the bone surface at the site of the cartilage plate. They believed this method to be about 90 percent accurate when used to separate sexually mature and immature male squirrels.

Although no inspection of dried bones was made by the writer, it would appear that the ossified condition described by Kirkpatrick and Barnett (1957) corresponds with the complete union of epiphyses and diaphyses shown in Fig. 1, lower right. If this is the case, then 3 of the 27 animals they assigned to the unossified group had attained sexual maturity sometime before 46 weeks of age (Table 1). Similarly, 7 percent of the 81 males classed as ossified were not sexually mature at this age. Direct comparisons must be made with some reservation because the present work deals with the radius and ulna, and ossification of the long bones of the body is not simultaneous.

Field Application

Only a small part of the foreleg is needed for aging purposes. A separation made about one-fourth of an inch above the wrist is adequate. As suggested by Petrides (1951), numerous specimens can be placed on an X-ray film after removing the phalanges. A 5- × 7-in. film can accommodate about 100 forelegs treated in the above manner. Specimens can be sexed from the developed film if, in the field, the right foreleg is removed from males and the left foreleg from females. Forelegs need not be examined immediately after collection. No change was evident in the X-ray appearance of the epiphyseal cartilage after specimens had been frozen 5 months. Sullivan and Haugen (1956) obtained satisfactory X-rays of dried fox forefeet several months after collection.

SUMMARY

X-ray examination of the distal epiphyses of the long bones of the lower foreleg of 10 hand-reared fox and gray squirrels revealed that adults can be safely separated from young-of-the-year between the dates of July 1 and January 15 for fox squirrels, and February 1 and December 1 for gray squirrels. Spring-born and summer-born young can be separated by this method.

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ESTIMATING TOTAL WEIGHTS OF BLACK BEARS FROM CARCASS WEIGHTS

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During 1957 and 1958, a study of the black bear (*Ursus americanus*) was undertaken in the northeastern section of Ontario, administered by the Swastika Forest District. The total weights of bears killed by hunters are difficult to obtain because most hunters skin or hog-dress their kills immediately. In order to obtain usable material, whole bears were collected. They were weighed, skinned, re-weighed, eviscerated and weighed a third time. Animals were skinned completely (paws left on the carcass) and eviscerated. No effort was made to account for blood loss at the time of the kill. A small beam scale (Fairbanks-Morse 400-lb. capacity) was used to obtain the weights.

Usable skinned weights were obtained from 19 animals ranging in total weight from 43.5 to 303 lb., and skinned dressed weights were obtained from 17 animals ranging from 43.5 to 267 lb. total weight (Table 1).

TABLE 1.—CARCASS WEIGHTS OF ONTARIO BLACK BEARS IN POUNDS

Total Weight	Skinned Weight	Skinned and Dressed Weight	Sex
43.5	38.0	29.5	♀
68.0	65.5	47.0	♂
100.0	88.0	80.0	♂
110.0	97.0	81.0	♂
113.0	99.0	80.5	♂
116.0	102.0	80.5	♂
123.0	106.0	86.0	♀
126.0	—	93.0	♀
128.0	103.0	86.0	♂
134.0	113.0	96.0	♀
155.0	136.0	113.0	♂
187.0	159.0	138.0	♀
198.0	165.0	135.0	♂
205.0	183.0	—	♀
222.0	201.0	165.0	♂
226.0	202.0	160.0	♀
255.0	228.0	—	♂
260.0	220.0	179.0	♂
267.0	237.0	187.0	♂
303.0	250.0	—	♂

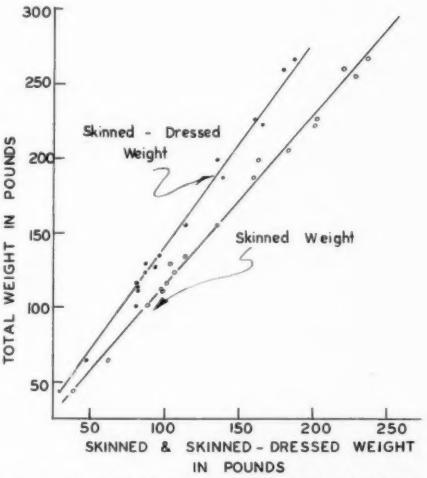

FIG. 1. Linear relationship between skinned and skinned-dressed weights and total weight for Ontario black bears.

Equations relating skinned weight to total weight and skinned dressed weight to total weight were calculated by the method outlined in *Applied General Statistics*, F. E. Croxton and D. J. Cowden, Prentice-Hall Inc., N.Y. 1939. These equations, $y = 1.86 + 0.86x$, for skinned weights and $y = 2.10 + 0.699x$, for skinned-dressed weights (with x = total weight) showed strong correlation giving a coefficient of correlation of 0.996 in both cases.

The standard error of estimate (standard deviation) was calculated at 5.4 for skinned weights and 4.1 for dressed weights.

No difference is noticeable in the relationship as it applies to the two sexes.

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FEEDING THE WHITE-TAILED DEER FAWN[1]

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Large numbers of white-tailed deer fawns are orphaned early in life due to highway kills and other mishaps. The raising of these animals presents a problem since very little information is available as to what diet is best to feed young fawns. Investigators at this station have raised fawns on Holstein milk after diluting it—two parts milk and one part water.

There is a scarcity of reliable data as to the composition of deer milk. Hagen (1951) analyzed milk secured from a freshly killed doe blacktail (*Odocoileus hemionus columbianus*) and found that the milk had approximately twice the total solids, ash and fat content of cow's milk. The Handbook of Biological Data (1956) reports that deer milk has approximately three times as much protein, five times as much fat, twice as much ash, and half as much lactose as cow's milk. Analyses of milk from the excised udders of four road-killed white-tailed does at this station (Cowan, 1959) indicates that doe milk contains about twice as much total solids and fat as cow's milk.

It is apparent from these comparisons that diluted cow's milk, as commonly recommended for fawn feeding, is a far cry from the natural diet of the wild fawn. With this in mind the present experiment was initiated to determine the feasibility of raising fawns on milk or milk replacer in a more concentrated form.

Procedure

Thirteen whitetail fawns (*Odocoileus virginianus*), 12 male and 1 female, were obtained from the Pennsylvania Game Commission during the period from June 4 to July 3. As sufficient individual pens were not available, all fawns were kept in a 10- × 24-ft. pen with shade and shelter provided, and had access to a 50- × 80-ft. exercise pen which contained a small amount of grass and browse. Each male fawn was assigned to its experimental diet when received. The last fawn was started on experiment on July 3, and the data used for the comparisons discussed below included only those recorded after this date. The first three fawns received were given undiluted evaporated milk (Group 1). The next three fawns were assigned to Group 2, and fed a commercial milk replacer formula. Those assigned to Groups 3 and 4 were fed pasteurized homogenized milk, and raw, whole Jersey cow's milk, respectively. The milk replacer (obtained from Eastern States Farmers' Exchange) was fed to Group 2 at twice the concentration recommended for dairy calves. The raw milk given to Group 4 was provided by a Jersey cow, pastured at a farm adjoining the deer pens. This treatment was included because it was believed that Jersey milk more closely approximated the composition of deer milk than milk from other dairy breeds. The raw milk was fed while still warm, immediately after milking, except during the period when the fawns were fed at noon. The other milk diets and raw milk used at the noon feeding were warmed to body temperature in ordinary baby bottles with slits cut in the rubber nipples.

All milk utensils used were sterilized prior to each feeding by being placed in a boiling water bath for at least 20 minutes. It is the opinion of the authors that maintaining a sterile condition in all milk containers is of prime importance in the prevention of scours.

The fawns were fed unrestricted amounts of their respective rations three times daily from July 7, 1959 until August 8, 1959. After this date twice daily feedings continued until September 12, 1959. Commercial calf starter, alfalfa hay, deer ration, and fresh water were available to the fawns at all times. The majority of the fawns had begun to supplement their milk diet with calf starter by August 1, 1959. By September 1, they showed a definite preference for the deer ration and alfalfa hay over the calf starter.

Composition of the fawn rations is shown in Table 1. A description of the pens used, watering

Table 1.—Composition of Experimental Fawn Rations (in percent)

	Dry Matter	Crude Protein	Crude Fat	Crude Fiber
Evaporated milk	27.5	6.6	8.0	–
Synthetic milk replacer[1]	20.8	6.4	0.2	0.3
Homogenized milk	13.0	3.5	4.0	–
Raw Jersey milk	17.2	4.2	4.8	–
Calf starter[2]	85.0	18.0	3.0	6.0
Deer ration[3]	85.0	14.2	2.7	13.6

[1] Milksaver—purchased from manufacturer, Eastern States Farmers' Exchange, Springfield, Massachusetts.
[2] Guaranteed analysis, Eastern States Farmers' Exchange.
[3] Long, *et al.* (1959).

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TABLE 2.—SEVEN-WEEK GROWTH AND FEED CONSUMPTION DATA FOR EXPERIMENTAL FAWNS, JULY 7–AUGUST 25, 1959

	Evaporated Milk	Milk Replacer	Homogenized Milk	Raw Milk
Average initial body weight (lb.)[2]	18.3 ± 4.4	16.0 ± 3.1	13.5[1]	16.8 ± 4.0
Average weekly body weight gain (lb.)[2]	2.8 ± 0.6	2.2 ± 0.9	2.6 ± 0.9	3.6 ± 0.6
Fluid oz. milk consumed daily per lb. of body weight	1.1	1.4	2.1	1.8
Grams dry matter consumed per lb. of body weight gain	666.0	636.0	468.0	551.0
Average total body weight gain (lb.)	19.5	15.3	18.0	25.0

[1] Only one fawn.
[2] With standard deviations.

system, and percentage composition of the deer ration is given in a previous publication (Long, *et al.*, 1959).

RESULTS AND DISCUSSION

Three fawns died of a coliform infection, a disease corresponding to "white scours" in calves. Serological testing of the organism showed it to be *Escherichia coli.*, strain 078, considered by many to be an enteropathogenic agent. Glantz (1960) isolated this strain of *E. coli.* from sick or dead lambs and calves. This coliform infection was possibly introduced into the group by a fawn that was seriously ill at the time it was delivered to the deer pens. One other fawn became sick with this disease, but responded to treatment. Due to possible setback, the feed consumption and body weight data of this sick fawn were not used in computation of average feed consumption and body weight gain. The above losses reduced Group 1 (evaporated milk) to three fawns, the doe being one, and Group 3 (pasteurized homogenized milk) to one fawn.

The average daily milk consumption in fluid ounces per pound of body weight (Table 2) was 1.06, 1.41, 2.14 and 1.78 for groups 1 (evaporated milk), 2 (milk replacer), 3 (homogenized milk) and 4 (raw milk), respectively. This was 9.4, 8.3, 7.9, and 8.7 gm. of dry matter daily per pound of body weight for groups 1, 2, 3, and 4, respectively. The percent dry matter of each ration as fed was evaporated milk 27.5, milk replacer 20.8, homogenized milk 13.0, and raw milk 17.2. The fawns receiving rations with the highest percentage of dry matter consumed the least volume of liquid. In the case of pasteurized homogenized milk, it appears that the fawn could not handle a sufficient volume of milk to equal the dry matter consumption of the other fawns.

The average total body weight gains over the entire experimental period were 19.5, 15.3, 18.0 and 25.0 lb. for groups 1, 2, 3, and 4, respectively, as shown in Table 2.

Dry matter consumption in grams per pound of body weight gain was in an inverse ratio to fluid ounces of milk consumed per pound of body weight gain. Since supplemental dry feeds were available to the fawns at all times, apparently fawns receiving rations with low dry matter content must have consumed more of the calf starter and deer ration than the fawns which received milk of higher dry matter content.

From these results it may be concluded that any of these milk products, or milk replacer, are suitable for raising fawns, but as the dry matter content of the milk decreases the need for supplemental dry feed increases.

To determine if the post-weaning rate of gain was influenced by the experimental treatments, weights for the 9-week period following weaning were examined. The largest weight gain (post-weaning) was by fawns which had been fed Jersey milk; they also had the largest gain in body weight during the experimental feeding period. The fawns fed milk replacer had the smallest weight gain both during and after the experimental feeding period. The average total gain of the fawns in the 9-week period following weaning was 28.9, 26.7, 28.5, and 30.0 lb. for groups 1, 2, 3, and 4, respectively.

SUMMARY

Evaporated milk, a commercial milk replacer, pasteurized homogenized milk, and raw Jersey milk were fed to four groups of white-tailed deer fawns over a 7-week period to compare the efficacy of these diets for raising fawns to weaning age. Average body weight gains in pounds for the fawns fed the various rations were evaporated milk, 19.5; milk replacer, 15.3; pasteurized homogenized milk, 18.0; and raw milk, 25.0.

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STRYCHNINE AS A POTENTIAL CONTROL FOR REDWINGED BLACKBIRDS

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Blackbirds have become a serious problem to producers of small grains in many areas of the United States. In the Lake Erie region of Ohio, where this study was conducted, bird damage occurred at corn-planting time and during the time when corn was in the milk stage. At corn-planting time, birds removed poorly covered seed from the ground and pulled sprouts. During late summer, while kernels of maturing corn were soft, birds freed the husk from the tip of the ear and fed on kernels near the tip. Mold damage developed after the ear was opened and water had penetrated between the husk and the ear. This late summer destruction was very severe locally. The redwing (*Agelaius phoeniceus*) inflicted major damage to soft corn, although some damage was caused by the cowbird (*Molothrus ater*), the common grackle (*Quiscalus quiscula*), and the starling (*Sturnus vulgaris*). Except for the redwing's depredation in grain fields, its diet consists largely of insects and weed seeds (personal communication from M. L. Giltz).

In recent years state and federal biologists have studied many possible solutions to this problem. They have used frightening devices such as rifles, shotguns, firecrackers, and scarecrows in an effort to reduce crop damage. In an attempt to move the birds, they have made tape recordings of various redwing callnotes and played them back through a loud speaker at blackbird-infested fields and at blackbird roosts. Some individuals have applied chemicals to grain in hopes of making it unpalatable for birds. Corn breeders are searching for a hybrid which is resistant to bird damage. Where the birds roost in trees in winter, roost bombing has been performed in an effort to reduce the population to an extent that crop depredation would be alleviated. Finally, birds have been killed with poisoned bait. Federal biologists recently killed birds in this maner in the Florida Everglades (Mitchell, 1955), the Lower Delaware River Valley (Mitchell, 1953), and the Arkansas rice belt (Neff and Meanley, 1957). The present paper concerns strychnine, the poison which they used, as a potential control for redwings. Presented are the results of two experiments in which 72 redwings were given oral doses of strychnine dissolved in water or were fed treated bait. Five baiting tests are summarized in which seven fields where redwings fed and a marsh where they roosted were baited with unpoisoned grain.

This study was made possible in part by a research assistantship granted by the Ohio Cooperative Wildlife Research Unit: Ohio Division of Wildlife, The Ohio State University, U.S. Fish and Wildlife Service (Bureau of Sport Fisheries and Wildlife), and the Wildlife Management Institute cooperating. Housing was provided during the course of the field study by the Ohio Agricultural Experiment Station. The writer is especially indebted to Eugene H. Dustman and Maurice L. Giltz for advice and assistance.

Toxicity Study

Unharmed redwings were captured for the toxicity study in two-leaved clover traps, in modified Australian crow traps, and in Japanese mist nets. Cages for the captured birds consisted of 2- × 4-in. framework measuring 6 ft. in each dimension and covered with 1-in. mesh poultry netting. A mixture of cracked corn and oats, and water were made available to the caged birds at all times before treatment. Each cage also contained a bird bath. The pens, which were located in an isolated area away from human disturbance other than that of the author and his assistants, were without floors and were placed over willow (*Salix* sp.) saplings. The vegetation served as perches for the birds, provided protection from prevailing climatic conditions, and served to attract insects into the pens, thus providing a supplement to the birds' diet of grain.

Confined redwings were maintained in pens for approximately 1 week prior to treatment, during which time the birds maintained their body weight, ± 2 gm. Strychnine sulfate was dissolved in distilled water and injected into each bird's stomach by means of a hypodermic syringe and no. 10 oral catheter. Each bird was nail-clipped and, following treatment, was returned to a holding cage where it was observed. Redwings that exhibited external effects from the poison had convulsions. After constant observation for 1 hr. (the longest time lapse from treatment to convulsion was 25 min.), birds not exhibiting any convulsions were placed in another holding cage containing food, water, and a bird bath [as were eventually all birds which survived]. The treated birds maintained body weight for the following 3 days, during which time they had no abnormal symptoms. Observational data included the percent of mortality, the time elapsing from treatment until the first convulsion, the time elapsing between successive convulsions, and the time from treatment until death or recovery. The effects of strychnine on an animal's system have been adequately described by Brundage (1926) and Best and Taylor (1952).

In toxicological studies, one is dependent upon the quantal or all-or-nothing response (Finney, 1947). Toxicologists commonly handle these data by employing a statistical treatment of the sigmoid

TABLE 1.—AVERAGE AND EXTREME TIME INTERVALS ASSOCIATED WITH REDWING CONVULSIONS FOLLOWING TREATMENT WITH STRYCHNINE SULFATE

Dosage (mg./kg.)	Number of Birds Treated	Minutes from Treatment to First Convulsion		Number of Convulsions per Bird		Minutes from Treatment to Death		Percent Dying
		Mean	Range	Mean	Range	Mean	Range	
0.0	6			No convulsions				0
1.0	1			No convulsions				0
1.8	1			No convulsions				0
2.5	6	15.8	14.0–19.0	1.0	1			0
3.8	5	5.5[1]	5.0–6.0	3.0	3	14.0	12.0–16.0	40
		13.3[2]	12.0–13.0	1.0	1			
6.0	18	5.9[1]	3.0–8.0	2.4	1–4	16.6	5.0–36.0	94
		6.0[2]	6.0	3.0	3			
15.0	5	3.4	3.0–4.0	1.0	1	7.7	6.0–9.0	100
30.0	4	3.4	2.5–4.0	1.0	1	7.7	7.0–8.0	100
50.0	5	2.2	1.5–2.5	1.0	1	5.6	1.5–8.0	100
100.0	3	0.8	0.5–1.0	1.0	1	1.6	1.5–2.0	100

[1] Birds dying.
[2] Birds recovering.

curve known as probit analysis. This method was employed to determine the LD_{50} and LD_{95} dosage of the poison. The median lethal dose of strychnine sulfate administered to redwings under the conditions of the experiment was 3.98 mg./kg. of body weight, with a variance of 0.068 and a standard deviation of 0.261 mg. The LD_{95} dosage under the same conditions was 6.48 mg./kg. A single convulsion proved fatal to the experimental birds which received strychnine above the LD_{95} dosage. Succumbing birds which received dosages in the LD_{50} to LD_{95} range most frequently experienced two or three convulsions, whereas surviving birds had a single convulsion. At very low dosages (1.0 mg./kg. and 1.8 mg./kg.), treated birds experienced no convulsions. Above the LD_{95} dosage, the time lapse from administration of poison to the first convulsion and from administration of poison to the time of death decreased as the level of concentration was increased. Within the LD_{50} to LD_{95} range of dosages, the average amount of time elapsing until the first convulsion was considerably longer for surviving birds than for birds which eventually succumbed (Table 1).

Variations in susceptibility to strychnine are due to the condition of the stomach (whether empty or full), the nature of the food present in the stomach, and differences in individual susceptibility. The stress of captivity may also have an effect on the toxicological reactions (McNally, 1937). I did not find any significant differences in susceptibility among the various sex and age groups, i.e., adult females, adult and yearling males, and juveniles.

GRAIN TOXICITY

Cracked corn was chosen as the bait to be treated with poison. Strychnine sulfate was dissolved in distilled water and applied to corn at the rate of 7.0 mg./kg. for a 65-gm. bird. This was 8 percent above the actual LD_{95} dosage (6.48 mg./kg.) and probably more than compensated for the small quantity of solution left adhering to the sides and bottom of the container. After the treated grain dried, the equivalent of one kernel, which was calculated to contain the 7.0 mg./kg. dosage, was administered to each of six randomly chosen redwings. None of these birds survived. Since few individuals of this species attain a weight of 65 gms., most birds received a dosage above the LD_{95}. Grain was also treated at higher dosages and force-fed to redwings. In general, the time lapse between the administration of the poison and the first convulsion and between the administration of the poison and death decreased with each higher dosage (Table 2).

A portion of the grain treated at 7.0 mg./kg. and 50 mg./kg. was exposed to prevailing weather conditions. Grain treated at 7.0 mg./kg. and weathered 1 day was lethal to all of the six randomly chosen redwings to which it was administered. This grain received 11 hrs. and 40 min. of sunshine and no rainfall. Grain treated at this dosage and allowed to weather for longer periods was lethal to 67 percent or less of the test birds, even though it was not subjected to any rainfall. Grain treated at a 50 mg./kg. dosage and weathered as long as 13 days was lethal to all of the six randomly chosen redwings to which it was administered. During this time the grain was sub-

TABLE 2.—REACTION DATA FOR REDWINGS FORCE-FED CRACKED CORN TREATED WITH STRYCHNINE SULFATE AT DIFFERENT DOSAGES

Dosage (mg./kg.)	Number of Birds Treated	Time Lapse (min.) from Dosage	
		to First Convulsion	to Death
7	6	13.7	53.3
30	6	5.5	19.3
50	6	5.0	21.3
100	6	3.2	7.3

jected to a total of 0.54 in. of rainfall and 96 hrs. and 44 min. of sunshine.

FIELD BAITING

The utility of the toxicological data was dependent upon field baiting tests. It was essential to learn first if untreated bait would be consumed by redwings. Poisoned bait could be used if and when successful baiting methods were developed.

We baited (without traps or poisons) from August 18 until the last week in October. Cracked corn was scattered and maintained in grid lines 3–12 yd. apart and in piles of 3–5 lb. from Sept. 1 to Sept. 26 in four fields of standing corn suffering heavy damage. Although the bait was observed 5 days of each week during various hours of the day, no blackbirds were observed to feed on the bait or even on the ground. On Sept. 23, a 1-a. patch of overripe sweet corn was chopped with a rotary mower which spread both ear and shelled corn over the field. During the following 13 days this field was observed for four or five 1-hr. periods on 8 different days. One flock of blackbirds composed of 45 cowbirds and 5 redwings was observed feeding in the field. Some of the more common visitors included the English sparrow (*Passer domesticus*), mourning dove (*Zenaidura macroura*), and ring-necked pheasant (*Phasianus colchicus*). On another occasion redwings from one of five major flight lines stopped daily in a 20-acre field consisting predominantly of ragweed (*Ambrosia* sp.) and smartweed (*Polygonum* sp.). I spread 25 lb. of cracked corn in a pile in each of four locations on cleared areas in this field. Bait was maintained from early September until early October, and I observed it 2 days each week while redwings were in the area. Pheasants were observed to feed on the bait five times, ducks twice, and redwings once. In the last instance, redwings feeding in ragweed in the immediate vicinity of a pile of bait eventually dropped to the ground in the cleared area. Sixteen birds sampled the bait, but their density within the baited area was not any greater than that in the surrounding area. At the North Central Substation Farm of the Ohio Agricultural Experiment Station, on August 19, a major portion of a morning flight line (an estimated 11,000 redwings) was observed to leave a roost and land in an oats stubble field ¼ mi. distant. An estimated 6,500 of these birds eventually shifted from the field onto a driveway nearby. A similar phenomenon was observed the following morning. Whole oats was then scattered in grid lines 4 ft. apart on the driveway. The third morning an estimated 2,000 birds stopped in the field, but none came to where the bait was located. On August 22 an estimated 3,000 of these birds landed in the oats stubble field and eventually made their way onto the driveway. There was no indication of the birds congregating on the grid lines of oats.

During each of these mornings the birds first stopped in the oats stubble field in the same location. In an effort to cause them to land elsewhere, I placed cracked corn and whole oats in 5-lb. piles in another section of the field. This bait had no apparent effect on the location at which the birds stopped. A cage housing a male and a female redwing was also placed in the vicinity of the scattered bait. This, too, had no apparent effect on the flight line of birds, as they continued to travel to the other end of the field. The birds within the cage, however, fluttered about continuously during this time.

Finally, on September 8, an area within a marsh directly adjacent to a roost was cleared of cattails. Thirty lb. of cracked corn were spread in a pile in this area. A like quantity of bait was placed on the other side of the roost, on a dike separating the marsh from a heavily depredated corn field. Throughout September and early October bait was maintained at these locations, and we observed it 4 or 5 days each week while birds were present in the area. Although the adjacent roost was utilized during this period, only a single redwing was observed at the bait. Noticeable quantities of bait were never consumed.

Baiting in Ohio at this time of year failed probably because of a preference by the birds for soft corn on the stalk. The single notable success in which federal biologists killed redwings which were consuming field corn was achieved by frequently flushing the birds from the field where they were feeding. The number of other cornfields in the area was limited and the redwings then came to piles of bait placed near the field from which they were flushed (Mitchell, 1955).

SUMMARY

A study of strychnine as a potential control for redwings was conducted from July to November of 1958 in the Lake Erie region of Ohio. The median LD of strychnine sulfate orally administered to wild-trapped redwings was 3.98 mg./kg., and the LD_{95} dosage was 6.48 mg./kg. Experimental baiting with cracked corn and whole oats in and along cornfields and other types of fields where birds regularly fed, in the vicinity of roosts, and along flyways regularly used by the blackbirds in leaving and returning to roosts was unsuccessful during the corn-damage season.

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EXPERIMENTAL STUDY OF NESTING BY COTURNIX QUAIL

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The coturnix quail (*Coturnix coturnix japonica* Temminck and Schlegel) has been introduced into many portions of this country as a possible addition to our wildlife fauna. This study was initiated to investigate certain life history sequences pertaining to nesting habits of the species, and to attempt to explain some of the ecological relationships affecting its reproduction.

The study was conducted at the Olentangy Wildlife Experiment Station in north-central Delaware County, Ohio, during the spring and summer of 1958. The study area consisted of a fenced enclosure of approximately 2 a., one-fourth of which was equally subdivided into three covered pens. Adequate fencing successfully controlled ground predators, and although avian predators presented little difficulty during the study, pole traps were mounted in the area as a precautionary measure.

METHODS

The coturnix used in the study were progeny of stock imported from Japan in 1953 (Stanford, J. A. 1957. Trans. N. Amer. Wildl. Conf., 22: 316–359). Six-month-old birds were placed within the enclosure during March and, as mortality occurred, more stock was added to maintain a density of approximately 15 pairs per acre. The coturnix were wing-clipped and tagged with plastic markers at the time of release into the enclosure. A 26 percent protein poultry feed was supplied in the early periods of the study, but feeding was discontinued when crop analyses of accidentally killed birds showed high utilization of natural foods.

Two workers systematically searched for nests at weekly intervals throughout the study. After nests were located, daily observations were made regarding the stage of nest development, number of eggs present, presence or absence of incubating hen, and the general nest appearance. Date of nest establishment was approximated by backdating from the time when incubation was considered to have begun. One day was allowed for each egg in the clutch and 16 days for incubation. No time interval was allowed between nest establishment and laying or between laying and incubation.

An electrical potentiometer recorded the temperature in each of 16 different nests every 8 min. during the incubation period. The thermocouple wires, extending from the instrument, were attached to the eggs with a plastic cement. The fine gauge of these wires permitted the eggs to be moved about by the nesting hen.

Photoelectric cell units from a burglar alarm system were used to measure periods of nest attentiveness. A relay switch that operated a pen on a revolving chart closed when a nesting hen broke the beam of light passing over the nest. An infrared filter was attached to the light source to prevent the light beam from disturbing the incubating hen's activities.

A simple switching device in the nest that opened and closed a relay was also used to record nest attentiveness. A loop of rigid wire that encircled the nest was used as a treadle arm for the switch.

Rainfall, air temperature, and relative humidity were measured with automatic recording instruments.

CALLING AND PAIRING

Although the coturnix has a variety of call notes, the mating call of the male is the most noticeable and common. It is heard during most of the nesting season, but intense calling appeared to be closely associated with initiation and peaks of nest establishment. Calling by males was first heard on the evening of April 25; the first nest in which eggs were incubated was established between April 24 and April 28. During the latter part of the nesting season, pairing and nesting took place even though no calling was heard. The intensity of calling was found to be highly variable during the day, but calls were most common in early morning and evening.

Pairing was indicated by the close association of a given male with a female throughout nest building, egg laying, and early stages of incubation. The same pairs of birds were repeatedly flushed close to each other. In several instances males, which were removed to the farthest corner of the enclosure, returned within a few hours to the area where they were associated with a given hen. Pairing appeared to be for only one nesting.

Although no birds remained paired until the young hatched, one bird, identified by plumage

[1] The Ohio Division of Wildlife, The Ohio State University, the Bureau of Sport Fisheries and Wildlife, U.S. Fish and Wildlife Service, and the Wildlife Management Institute cooperating. Appreciation is expressed to E. H. Dustman, William R. Edwards, and Clifton Breece for their assistance during this study. The study was conducted as a portion of Federal Aid in Wildlife Project W-103-R.

as a male, was observed with a recently hatched brood. Two others similarly identified were observed incubating nests. Such sex identification, however, is not infallible in this species.

NESTING

Nesting was initiated at about the same time that calling began. Three nests found on May 5 contained 3, 10, and 12 eggs, respectively. Backdating indicated that the first nest was established about April 26. Young hatched from two of these nests on May 18 and 20.

Nesting was completed when one bird hatched five of a clutch of seven eggs on August 14. Other nests were completed within a few days prior to August 14. The frequency of nest establishment in 35 nests was as follows: April 26–30, 1 nest; May 1–15, 2 nests; May 15–31, 4 nests; June 1–15, 8 nests; June 15–30, 12 nests; July 1–15, 5 nests; July 15–31, 3 nests.

Coturnix utilized a variety of different sites for nesting. Early in the nesting season, when the green vegetation was primarily grasses and young weeds, the birds chose nest sites in areas of heaviest growth. As the season progressed they moved into areas of relatively sparse cover, such as an area of low growing herbaceous plants.

A coturnix does very little nest construction before initiation of egg laying. After laying the first egg in a shallow, scratched-out depression in the ground, the hen adds a small amount of dead straw or weed stems to the nest at each egg laying. Rarely is there much insulating material in the bottom of the nest, and feathers or down have never been observed in nests. The completed nest has the appearance of a miniature ring-necked pheasant nest. Twenty-four nests were measured. The following is a summary of these measurements: outside diameter, 6–7 in.; inside diameter, 3½–4½ in.; inside depth, 1¼–2 in. There was no canopy or bower over any of the observed nests.

Clutch size ranged from 4 to 14 eggs. The majority of the nests contained 8 to 12 eggs. The mean clutch size for all incubated nests found was 9.8 eggs; for successful nests, 9.2 eggs. Thirty-five nests were incubated; 29 of these were successful. The mean hatching percentage of these 29 was 67.1 percent. Hatching success varied from 18 percent to 100 percent. Although only a few nests were observed completely through egg laying, the average rate of laying of 54 eggs in 5 nests was 1.14 eggs per nest per day.

Many biologists were particularly interested in knowing whether the species would successfully nest more than once during the same season. Stanford (1957) wrote, "In much of the literature we find statements that the birds 'probably,' 'possibly,' or 'undoubtedly' produce two or more broods per year. There is not much documented material on the multibroods of the bird, but those who are qualified to say have weight of evidence for possibly two broods per year." R. E. Moreau (1951. Brit. Birds, 44:257–276) gives some indirect evidence of at least two broods per year.

During the present study, of the three birds first found nesting on May 8, two were incubating second clutches on June 24. These birds hatched young from the first nests on May 18 and 20. The second nests were established within 20–25 days after the first were hatched. Two additional females produced second nests during July and the interval between the termination of their first nest and the initiation of their second was only 16–20 days. Thus, a total of four hens definitely produced two broods during the same year.

The two female birds that hatched first clutches on May 18 and 20 and second clutches on June 30 and July 2, respectively, were incubating third clutches during a nest search conducted on July 28. The clutch sizes were smaller, but nests were well constructed. Again, the interval between nestings was about 20 days. The third clutches hatched on August 13 and 14.

From our studies we have found that coturnix become sexually mature while still wearing juvenile plumage and in confinement produce fertile eggs when 36–40 days old. Although many juvenile birds remained in the study area, nesting by young-of-the-year was not observed. Two subadult females, however, incubated nests in Fayette County, Ohio, where a wildlife agent positively identified the banded hens. Records showed that the hens established their nests when approximately 67 days old. In the study area no distinct pairing bond involving a juvenile bird was observed nor were any juvenile hens associated with nests. Dissection of subadult females 8 to 10 weeks old revealed that the ovaries had developed to a maximum of only 1–2 mm. in diameter, much less than in laying birds.

Nest desertion was limited to instances where nest or egg damage occurred. Most of the birds that deserted nests renested 10–20 days later. Five hens were undisturbed during their second attempt, and four nested successfully.

ECOLOGICAL RELATIONSHIPS

An attempt was made to ascertain the effect of the environment on nest attentiveness and hatching success of the coturnix. Data regarding nest attentiveness and hatching percentages on 10 nests were compared with the weather information recorded by the automatic instruments. A statistical analysis indicated the following general relationships: (1) As the amount and duration of rainfall increased during a given incubation period, hatching percentages decreased; (2) rainfall values did not correlate with temperatures of eggs in the nest nor with duration of inattentive periods; (3) significant differences were found in average incubation temperatures and ranges of temperature fluctuation in various nests; and (4) neither air temperature nor relative humidity was correlated

TABLE 1.—DATA COLLECTED FROM NESTINGS OF COTURNIX QUAIL UNDER EXPERIMENTAL CONDITIONS

Hen Number	Hatching Percentage	Rainfall Index[1]	Average Daily Inattentive Period (hours)	Average Egg Temperature During Incubation (degrees F.)[2]	Standard Deviation of Egg Temperatures During Incubation
1	90.0	.4	3.2	96.2	± 4.32
2	100.0	.2	5.6	95.7	± 9.18
3	61.5	1.6	5.2	96.9	± 6.41
4	40.0	2.2	5.0	98.1	± 5.76
5	36.3	2.9	4.6	97.4	± 5.11
6	70.0	1.0	3.9	98.9	± 3.22
7	44.4	2.5	5.9	97.5	± 7.84
8	45.5	2.8	6.6	94.8	± 8.93
9	58.3	1.6	6.5	96.5	± 6.72
10	55.5	2.3	4.8	96.9	± 5.99

[1] Rainfall index = $\frac{\text{Inches of rain during incubation}}{\text{Hours that rain fell during incubation}} \times \text{Number of rains during incubation}$

[2] Only temperatures recorded when hen was incubating were used in computation of the incubation temperature.

with hatching percentage or nest attentiveness. Table 1 contains a summary of these data.

SUMMARY

A study to investigate nesting habits of coturnix quail and some effects of environment on its reproduction was conducted in an enclosure. Calling was closely associated with nesting during the April 26–August 14 nesting season. A hatching success of 67.1 percent was observed in 29 scantily built nests. Although no young-of-the-year nested, four adult birds produced two broods and two adult birds produced three broods during the same season. Rainfall was inversely correlated with hatching success but showed no relationship with egg temperatures or nest attentiveness.

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A MODIFICATION OF THE NICOTINE DART CAPTURE METHOD

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In order to study the social behavior and movements of a population of white-tailed deer, *Odocoileus virginianus,* in central Pennsylvania, it was necessary to capture and mark a considerable number of animals for individual recognition and observation. Since efficient trapping of deer is limited to a few months during the winter when food is relatively scarce, an alternative capture method was necessary. An attempt to use a commercially available nicotine dart and propelling device proved unsuccessful because the range and accuracy of the weapon were not sufficient for the hunting conditions encountered. A small, inexpensive dart with superior flight characteristics was devised and used. Details of the construction and use of the dart are presented in this paper.

Early experiments have indicated that a curare-like drug, Flaxedil, could be used to anesthetize deer when an antidote could be quickly administered, but Flaxedil was not suited for field use. Strychnine salts were used to capture wild deer, but proved unsatisfactory because an antidote was required and fatalities were common (Jenkins, *et al.,* 1955). Nicotine salicylate has been successfully used to anesthetize wild deer. It, when mixed with honey to form a paste, was packed into a solid dart and shot into the animals (Crockford, *et al.,* 1957a). More recently, solutions of various concentrations of nicotine salts have found widespread use as anesthetizing agents for use in the field. The material is typically introduced into the animals with a "flying syringe" dart (Crockford, *et al.,* 1958). Deer have a relatively wide range of tolerance to nicotine compounds. The drugs may be used without an antidote, and thus are relatively safe for field use.

DART CAPTURE METHOD

An attempt by the author to use the flying syringe dart (Crockford, *et al.,* 1958), sold by the Palmer Chemical and Equipment Company, Atlanta, Georgia, was unsuccessful. Sixty hours of hunting effort resulted in the marking of only one animal. The effectiveness of the syringe dart was limited by the shortness of its effective range, due primarily to the large size of the projectile and its resulting resistance to flight. Smaller, solid darts with adequate flight characteristics had been previously used (Crockford, *et al.,* 1957a), but a mixture of the anesthetizing drug with an inert substance disintegrated too slowly for successful field use. A paste type load had been shown to be adaptable to a small dart which offered less resistance to flight (Hall, *et al.,* 1953). A carrier substance which would allow the drug to be released quickly appeared to be necessary for adapting the drug-dart method to our hunting situation.

The author reasoned that an effervescent material would react with the tissue liquids and re-

lease the active portion of the mixture within a short period of time. Experiments revealed that a mixture of a commercial effervescent and nicotine alkaloid, an oily liquid, formed a sticky paste. This mixture separated in less than 1 minute in cold water. The nicotine was freed from the mixture as the effervescent reacted with the water. A mixture of 3 parts effervescent to 2 parts nicotine by weight had the proper molding consistency and cohesion.

Darts for use with this mixture were cut from brass or copper tubing of an appropriate diameter. It was found that an effective dose of nicotine, 270–330 mg. (Feurt, *et al.*, 1958), could be contained in a dart 1¾ in. in length. Blanks 1¾ in. long were cut from stock ⅜-in. o.d. brass or copper tubing. Acid core solder was used to build up a ¼-in. head which was filed to a point. Two alternating ½-in. notches were cut in the dart with a jeweler's saw. A yarn tail was twisted into the back of the dart and clipped square to a ¼-in. length. The drug and effervescent mixture was packed into the dart by hand and the dart was rolled on a smooth surface to insure complete packing. The completed dart was about 2 in. in length and weighed 2.5 to 3.5 g. loaded.

The dart was fired through a .20 cal. Sheridan air rifle or a .22 cal. Crossman gas powered rifle. Both range and field tests of the dart indicated that it had a range of at least 75 yd. A workable pattern was achieved at ranges of 50–60 yd., with shots grouped within a 4-in. circle.

The dart designed in this study had certain advantages. It could be rapidly constructed from materials which were inexpensive and easily available. The cost was about $0.04 per dart. It fit a standard caliber gun which could be easily modified for its use. The dart had about 30 percent more range than previously successful darts. The effect of the nicotine when introduced with an effervescent was more rapid than when introduced with an inert paste carrier, and comparable in rapidity to the effect achieved through injection by a syringe dart.

The dart had disadvantages not completely outweighed by its low cost, longer range and ease of construction. The flight of the dart was erratic at times, possibly because of the non-standard conditions under which it was made, and the resulting variable dart weights and shape of the points. A disadvantage in the use of this dart was its deep penetration. Darts recovered from six deer which were autopsied were located up to 2½ in. below the skin. This depth of penetration made it impossible to remove some of the darts without surgery. Darts were easily recovered from 22 of 51 deer captured. We decided that more damage to the animals would result from surgery under field conditions than from the presence of the dart in the musculature of the deer. Observations of recently marked animals indicated that symptoms of discomfort were minor or absent, disappearing within 2 weeks. The autopsy of one deer which died of natural causes during the study, and the examination of three deer killed during the hunting season, bore out the prediction that the dart would be walled off with connective tissue.

Forty-four deer were captured through the use of this dart. In addition, seven animals captured in traps were anesthetized with darts to facilitate handling. Eight fatalities occurred through the use of the dart. Four deaths were diagnosed as having resulted from nicotine poisoning, apparently from an overdose of the drug, although the same dosage had been succesfully used on other deer of comparable sizes. Two deer were destroyed after darts fired at a short range penetrated large nerve trunks and paralyzed portions of the hind quarters of the animals. Two deer were destroyed after they received mechanical injuries during the excitement period of reaction to the nicotine. Fifty-one deer were successfully marked through use of the dart, while 8 were killed. Crockford, *et al.*, (1957b) reported 12 percent mortality, with 4 of 141 deer lost to mechanical difficulties unrelated to the drug and 13 of 141 dying of causes directly related to drug action.

Although the dart we devised proved workable, the technical disadvantages and the possibility of leaving a large foreign object in the body of a game animal outweigh its advantages for general use. Further developments in small, accurate darts with reduced penetration are needed to make the dart capture method generally applicable.

SUMMARY

An attempt to use the flying-syringe dart proved unsuccessful. The author devised a small dart which utilized nicotine alkaloid with a commercial effervescent as a carrier substance. Fifty-one deer were marked through use of the dart. Fourteen percent mortality resulted from various causes related to use of the dart. The advantages of the modification over earlier model darts were longer range, greater accuracy, and lower cost. The major disadvantage was deep penetration of the dart.

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OBITUARY

W. J. K. Harkness

1896–1960

Dr. W. J. K. Harkness, B.A., M.A., D.Sc., Chief of the Fish and Wildlife Branch of the Ontario Department of Lands and Forests, died in Toronto July 5, 1960 after a brief illness. Of international repute in the field of fish and game management and conservation, he was a Commissioner of the Great Lakes Fisheries Commission and had been honored with the presidency of the American Fisheries Society (1951–52) and of the International Association of Game, Fish and Conservation Commissioners, an office to which he was named at its convention in Toronto in 1956.

Born in Iroquois, in Dundas County, Ontario, in 1896, he received his early education in the vicinity and at St. Catherines. A University of Toronto graduate, he lectured at the University of Alberta, 1922–23, and then received his Master's degree at the University of Toronto. From 1924 to 1945 he was on the staff at Toronto in the Department of Zoology as Associate Professor of Limnology. He received the degree of Doctor of Science from The Ohio State University in 1946.

While at the University of Toronto he was director of the Ontario Fisheries Laboratory. In 1937, at Lake Opeongo in Algonquin Provincial Park, he supervised the establishment of Ontario's first permanent field headquarters for fisheries research.

During his association with the University of Toronto, Dr. Harkness was loaned "on exchange" to two American universities, the University of Florida and Ohio State.

In 1946, when the then Game and Fisheries Department of the Ontario Government was amalgamated with the Department of Lands and Forests, Dr. Harkness was appointed Chief of the Division of Fish and Wildlife, now the Fish and Wildlife Branch of the Department of Lands and Forests. In this new field he is credited with having introduced a great many of the modern principles of conservation and fish and game management which he had espoused and developed in the course of his career.

Along with his popular and scientific writings, Dr. Harkness was known for his contributions to numerous provincial, dominion and international conferences. A major paper on the sturgeon, covering years of research, is in the process of being published. Other important fields of interest in which his influence was felt are training in fisheries and wildlife management, wetland management, pollution control and hunter safety.—C. H. D. Clarke.

BOOK REVIEWS

Multiple Purpose River Development. By John V. Krutilla and Otto Eckstein. Johns Hopkins Press, Baltimore. 1958. xiv+301pp. $4.50.

This book is an application of the fairly well defined area of economic theory known as welfare economics to the problems associated with multiple purpose river basin development. At the very outset the authors draw a valuable and pertinent distinction between what they call equity or political considerations and efficiency or economic considerations. They appropriately limit themselves to an investigation of the latter while recognizing that equity considerations often determine the nature and extent of the nation's water development programs.

A basic assumption underlying the analysis undertaken in this work is that only the effects upon *national* income and product efficiency are considered by the authors. However, they point out that *regional* effects may well differ from national effects, especially in those instances where resources presently are used outside the region undergoing development. In describing the characteristics of multiple purpose river basin development, the uses of water for human consumption, agricultural and industrial purposes, navigation, waste disposal, wildlife propagation, flood control, and power are succinctly summarized. The physical and institutional environment is also sketched concisely but well.

In discussing the concept of efficiency, the authors draw a distinction between technical performance levels, such as the amount of fuel required to produce a kilowatt-hour of electricity, and economic efficiency. In general terms, maximum economic efficiency is attained when no reshuffling of resource use can improve one individual's position and yet leave every other individual in as good a position as he was before the change. Any change, of course, benefits some individuals in a society, but if this is achieved solely at the expense of other individuals, there is no net gain to the group as a whole but merely a redistribution of output within the society. Of course, such a redistribution may be desirable for reasons of equity which lie outside the scope of the task the authors have set themselves.

The authors proceed with their discussion of economic efficiency by summarizing what economists call allocation theory and capital theory under conditions of pure competition. That is, they consider the nature of the considerations and the mechanism by which consumers choose between work and leisure, between consumption and saving, or between one good and another when no indi-

vidual can, by his actions, influence the demand, supply, or price of any good. The shortcomings of this competitive model for use in analyzing water resource development programs are then pointed out. Chief among these compromises with the theoretical model are the problems of group versus individual wants (e.g., the inability to provide flood control for some users of the flood plain without providing flood control for other users also); interdependence between production and consumption (e.g., water used for irrigation also recharges under ground aquifers); indivisibility in production (e.g., the amount of water necessary to maintain a 9-ft. channel also provides minimum flows which mitigate pollution); and the existence of "higher" goals (e.g., the maintenance of full employment in the nation or region or the preservation of esthetic values).

Perhaps the most controversial section of this work is devoted to a discussion of an appropriate rate to be used as representing the social cost of capital in government (primarily federal) water development projects. While it is generally agreed that such a charge is an integral part of the cost of a project, there is considerable dispute as to its level. It has been argued, on one hand, that the rate should approximate the return earned before taxes by the most efficient private enterprises on their invested capital, or something in excess of 20 percent. On the other hand, most federal agencies argue for and use the interest rate on long-term government bonds (about 2 or 3 percent) as the proper measure of the social cost of capital. The authors reject both these alternatives, as well as a number of others that have been advanced from time to time, in favor of what they term a "sector-by-sector approach, assuming a specific incidence of marginal taxation" (p. 91). Their method attempts to take account of the actual structure of capital flows in the economy and the interest rates applicable to the several sectors. An estimate of from 5 to 6 percent is eventually arrived at as approximating the social cost of capital to the federal government. In the reviewer's opinion, this estimate is probably more nearly accurate than the alternatives indicated above. However, the authors' own caution that the criterion of economic efficiency is not the sole criterion should be underscored.

Approximately half of this volume is concerned with the application of the methodology outlined to problems in specific development situations: the comparative efficiency of alternative proposals in the Hell's Canyon reach of the Snake River and on the Alabama-Coosa River systems; and the distribution of costs and gains among economic sectors from alternative proposals for the Willamette River in Oregon. These sections will not be reviewed here and we will pass on to the concluding section of the work where certain policy implications are drawn by the authors.

A primary conclusion is that, given the inadequacies of competitive market forces to embrace every variety of economic good (e.g., national defense, flood control, and pollution abatement), public funds must be used if these services are to be provided. The vehicle for public participation may range from a local single purpose agency through state and regional institutions to the federal government. If a policy decision for more private participation in multiple purpose river basin development is made, legal institutional changes must also be made if economic efficiency objectives are to be achieved (e.g., payment for downstream benefits of upstream water regulation, and institutions for coordination of reservoir operations). To this reviewer, the analysis in this volume builds a strong case for a supra-local institution with governmental or quasi-governmental powers which is not either confined by present political boundaries or restricted in function to only a few of the possible purposes of water development projects. The exact form and powers of such an institution are less important than the recognition that efficient multiple purpose development requires responsibility for planning and coordination to be centralized in a single agency. —WILLIAM IULO, Bureau of Economic and Business Research, Washington State University, Pullman, Washington.

Viltvård av i dag, Amerikanska intryck (*Wildlife Management of Today, American Travel*). By Bo Österlöf. Nordiska Museet och Skansen-Svensk Natur, Stockholm, 1957. 136 pp. 13.50 Swedish Kr. ($2.61).

The author of this book[1] is the assistant forestry chief of one of the large landowning companies in Sweden. In 1954 he spent 2½ months in the U. S. A. studying administration and management of wildlife resources. There is no doubt that he was impressed by what he saw on visits to Alaska, Washington, Oregon, Minnesota, and Washington, D. C. He uses these favorable impressions to inform Swedish sportsmen of what U. S. biologists consider a modern program of wildlife research and wildlife management.

The book is not a travelogue by any stretch of the imagination. Instead, the American travel is used as a framework on which to hang a surprisingly clear survey of modern American principles of wildlife ecology and wildlife management. The purpose of the book, from start to finish, is to convince the Swedish reader that animal populations are dependent on use of the land and that American principles and methods of wildlife management should be applied in Sweden.

The fundamental principles of ecology and wildlife management are woven into the book in many places and in many ways, so that the reader finds the main conclusions quite inescapable. The American often forgets that he is reading about North

[1] The reviewer wishes to thank Mrs. John A. Strand and Mrs. William L. Webb for translating this book.

American travel, as the first half of the book deals largely with these principles. There are chapters on the states visited, but even here emphasis is on basic ecological and management principles. For example, Österlöf first refers to the relation of soil fertility and animal populations in an early chapter—"Nature's Wealth"—where he especially emphasizes that good buffalo populations were the product of fertile soil (the debt to Durward Allen is clear). Later he devotes a chapter to "Viltbonetet" or wildlife site-quality where the subject is more thoroughly discussed. Throughout the remainder of the book Viltbonetet is so frequently mentioned that even the most urban reader must agree that wildlife is a product of the land and cannot be considered separately from the soil from which it springs.

In only a few places the author displays a personal reaction to what he actually saw on his American travels. To any Swedish visitor, the amount of money available for wildlife research and management in the U. S. would be overwhelming. Bo Österlöf's awe shows through in a few cases, but his awe is not jealousy. He concludes that a fund-raising tax like the P-R or D-J programs would be good for Sweden. In another place the reaction of a Swedish forester to the unmanaged American forests is revealed. The author describes a long auto trip in Minnesota through an area which had, before the logging and fires, grown a conifer forest. The car passed through many miles grown up to a tangle of birch, aspen, maple, and bushes. He wryly remarks that to a Swedish forester Minnesota's forestry looks a little careless and a little funny.

Österlöf believes that Swedish wildlife management is 30 years behind that of the U. S. A. He believes this is because a great knowledge of ecology of American wildlife has been developed through research. He was so impressed with the quantity of wildlife research completed and under way that he could only write a single-page chapter on research which is entitled "Research, Research and More Research." Throughout the book he gives examples of research projects which he saw or read about.

In a final chapter, Österlöf draws some conclusions regarding Sweden's use of the principles of today's wildlife management. Here, there can be little doubt that he personally is a firm believer in the ecological approach to wildlife management. He discusses the possibilities of habitat management in Swedish forests and fields, the dangers of introduction of exotics, the use and abuse of refuges as a management tool, the place of predators in an animal community, and especially the need for investing in research on the biology and ecology of Swedish wildlife and wildlife environments. He counsels that the ecology of Swedish animals and Swedish vegetation be thoroughly studied, and presents a 16-point program to modernize Swedish wildlife management.

The American wildlife manager reading this book tends to get a little thrill from realizing that one European is saying, loudly and clearly, "The Americans are on the right track and are way ahead of us." No American wildlife manager can take too much pleasure from this, because we know there are too many blank spots in our knowledge, and too many sour spots in our practices. Österlöf treats us with kindness in his zeal to convince his countrymen of what should be done in Sweden.—WILLIAM L. WEBB, State University College of Forestry at Syracuse University, Syracuse, New York.

A Field Guide to the Birds of Texas. By Roger Tory Peterson. Published for the Texas Game and Fish Commission by Houghton Mifflin Company, Boston, Massachusetts. xxx + 304pp. $3.00.

Peterson's *Field Guide to the Birds of Texas* already has become a best seller—and this without advertisement except the mere announcement that the book was off the press and could be obtained for $3.00 by writing the State Game and Fish Commission, Austin, Texas. This, itself, indicates the public need and demand for an aid to bird identification in this far-flung state. The popularity of the book reflects both unbounded confidence in the artist author and a growing interest in the amazing bird fauna of this great commonwealth.

The famous Peterson *Field Guides* have become a public necessity for both accomplished and amateur naturalists. They are popular because they are understandable and readily usable regardless of the degree of experience and competence of the user. The series is a synthesis. Each book and each revision since the first 1934 *Eastern Bird Guide* has been an improvement over the one preceding. The *Texas Guide* is no exception. This latest book in the series is the best yet and it effectively combines the artistic beauty of the illustrations with succinct, scientifically accurate and readable text which emphasizes the primary distinguishing features of each of the 542 species of Texas bird life.

This amazing list of species represents three-fourths of the existing fauna found between Mexico and Canada and about 100 species more than are known to occur in California, the state with the next largest number of kinds of bird life. The great diversity of habitat, rainfall, climate and topography in Texas, along with its mammoth size and geographic position, make it a meeting ground for bird life from the north, east, south and west. Consequently, no one previous field guide adequately covered the species to be found here and the bird student found it necessary to carry a series of cumbersome guides that were available for other sections of the country. Therefore, there was a strong demand for a specific guide to cover the birds of this great state.

It is to the great credit, wisdom and foresight of the State Game and Fish Department that it

recognized the need and generously allotted $60,000 to guarantee publication and to insure a selling price far below the actual cost of the book. This put the selling price within the reach of school children and those who need the book most. The Department recognized that its responsibility must transcend the care, protection and management of just game species. On the contrary, it felt that it must be concerned with the state's total wildlife resources. Its objective was to educate and inform the people of the state of their rich heritage that they might more fully enjoy and conserve this priceless resource.

This pocket book of 304 pages plus 30 pages of essential introductory data is remarkable in the wealth of information it presents. It contains 60 full-page plates, 36 in color, with numerous text drawings to further illustrate various species. Confusingly similar species are differentiated by patternlike drawings in which key field marks are indicated by arrows. The book contains 2 well prepared area maps of Texas and 13 pages of silhouettes of birds.

The splendid paintings, drawings and diagrams give remarkably good visual helps in bird identification to the student. The text clearly and succinctly describes the manner of flight, range, season of occurrence, and preferred habitat of each species; it also points out distinguishing differences of other birds that might be confused with it and how these related or similar-appearing species can be differentiated in the field.

The text describes in systematic order 487 basic or more common species and in an appendix separates the rare or accidental and hypothetical species. Another short section treats of the introduced, extinct and vanishing state birds. The book also contains a concise checklist to enable the student to keep seasonal, annual, or life lists.

The author generously credits many local ornithologists throughout the State of Texas with previewing the manuscript and with supplying accurate facts. There is little doubt that this careful and widespread preview aided in keeping errors to a minimum. The errors in the book are so minor and rare that to this reviewer only commendation and praise can be expressed. This book sets a new high standard of excellence and achievement.—CLARENCE COTTAM, Director, Welder Wildlife Foundation, Sinton, Texas.

Conserving Natural Resources: Principles and Practice In a Democracy. Second Edition. By Shirley Walter Allen. McGraw-Hill, New York, 1959. ix + 370pp. $6.75.

This book is a revision of a college text first published in 1955. The present edition maintains the general format of the original; it includes an additional 23 pages and a reemphasis, or new discussions, on water, conserving the atmosphere, and the peaceful uses of atomic energy. Forty of the 172 illustrations are new but many of these serve as replacements for figures deleted from the first edition. The illustrations are generally good although many of the reproductions in the review copy seem to have lost some of their clarity when compared to the first printing. The new index of 10 pages appears somewhat condensed from the previous 10½ pages of smaller print. A "bibliography" is appended to each chapter, though many of the references are not cited in the text. Footnotes are employed throughout.

The first 19 pages comprise an "Introduction" in which the author defines general concepts and outlines the development of the conservation movement. Pertinent terminology is handled separately in the introductory material of each of the later chapters. For convenience, Allen rearranges the six common natural resource classes into three major categories, *viz.*, "Inexhaustible," "Replaceable and Maintainable," and "Irreplaceable." This leads to a division of: "Water in its cycle" under one heading and "Water in place" under another. Such a dichotomy may be questioned on semantic grounds, but the outline itself presents an interesting entity.

Chapter 2 considers "The Land, the Soil and Conservation." The ostensible redundancy of the third element in this heading is rationalized, we suspect, by the preponderance of techniques and preventive measures included in this well-written section. The third chapter discusses the uses of water and aspects of its conservation. Appropriately enough, the polemic areas of flood control, drainage, and irrigation of "reclaimed" lands are here *introduced*. Unfortunately, the discussion of the last two topics is characterized by a distressing failure to *explore* their multiple ramifications for the benefit of the relatively unsophisticated and potentially influential audience at which the book is aimed. The only reservation in over 20 pages devoted to River Valley Projects and related topics arises in the discussion of the "somewhat hastily drawn" Pick-Sloan plan, and points out that the only hope for unified management in the project lies with the Missouri Valley Inter-Agency Committee (pp. 91–92). A footnote in another section (p. 110) recalls the halfhearted policy of the construction agencies in acquiring lands bordering reservoir sites to enhance recreational values, but in general the accounts of Army and Reclamation Bureau activities read like the material turned out by their own biologists. The currently stylish term "multiple purpose" crops up repeatedly here and elsewhere (pp. 88, 98, 110, 178, 205), but nowhere is the reader exposed to a critical discussion of the practical considerations which this term glosses over. One wonders if the limitations of the Wildlife Coordination Act (p. 235) and the sentence or two regarding dams and fish production (p. 245) might not have been appropriately included in this section. The TVA descriptions are panegyrical. Food surpluses do not enter the picture. The terms "wilderness" and

"natural areas" are conspicuous by their absence, both in the index and throughout the book. Elsewhere the author points out the "priorities" aspect of resource management (pp. 178, 239, 245), but fails to link this strongly to the population problem. Overpopulation problems are relegated to a page or two in the last chapter. In comparison, the flood control controversy fares much better, since both sides of the coin are at least in evidence.

Allen's professional training and experience as a forester are manifest in the general excellence of Chapter 4 which groups, not altogether arbitrarily, the discussions of "Forests, Grazing, and Recreation." One might wish for a little stronger language regarding the perennial land-grab attempts of some western livestock interests (p. 190), or some proselyting for more realistic appropriations in Congress for the National Park Service and other such bureaus. Nevertheless, this chapter is among the best in a generally well-written book. For the wildlife biologist, Chapter 5 will probably occupy the other end of the spectrum, technically if not esthetically. Here again semantic difficulties arise when "wild-animal life" is substituted for "wildlife" in an attempt to narrow the field of discussion (p. 208). Further limitations are evident in the statement regarding the mackerel fishery: ". . . *in spite of* amazing egg production, as high as 500,000 by a single female, mortality of young fish is high" (p. 258) (italics ours). The author includes grouse and turkeys among the animals constituting "the bulk of the take in farming country" (pp. 217–218), and wolf and fisher among the "most frequently captured" fur animals (p. 220). More serious objections, however, concern the ill-advised use of such terms as "useful wild animals" (p. 212) and "beneficial and predatory" (p. 229). He subscribes to the classical fallacy that the redeeming feature of the predators hinges on their "capturing diseased and crippled specimens" (p. 228). Artificial propagation and restocking are rather mildly censured as management practices (p. 227), but habitat manipulation, though not particularly emphasized, is at least well recommended. It was rather disappointing to find neither Durward Allen's "Our Wildlife Legacy" or Leopold's classic "Game Management" listed in the bibliography for the chapter. Despite this deficiency, as a chapter in a general conservation book this one covers a lot of ground and reflects a gratifying awareness of the importance of research, flexibile policy, and public education.

The factual material included in the 72 pages devoted to mineral resources in Chapter 6 is largely derived from federal publications. The treatment is confined to mineral fuels, the metals, and the nonmetallic fuels, and is well handled. Here, as elsewhere, some interesting trends become apparent when current figures are compared with those in the earlier edition. Such information in an appendix would have been a valuable, albeit laborious, addition to the book. A new section on nuclear energy as a power source furnishes brief discussions of various types of reactors and suggests some of the problems involved. In the final brief but unique chapter the author takes a candid look at the cause and prevention of some of the deterrents to man's achievements in our so-called civilization. The book is clearly written throughout, and occasional bits of humor or picturesque phraseology serve to enliven what is generally a straightforward statement of facts and philosophy.

Allen's treatment of conservation is particularly noteworthy for the emphasis placed on the social, economic, and even political aspects of the problem. The incisive, factual accounts of the activities in Washington which bear upon our natural resources should prove a revelation for many readers, though some may feel that the treatment is slightly bipartisan (pp. 12–14, 16, 59, 103). The work is well documented and reflects the author's wide acquaintance with the literature. The extensive compilation of current figures in tons, acres, board feet and noses constitutes one of the outstanding values of the text.

Book reviewing is a humility-building process, and to take issue with the author of such a "well-researched" volume as this is perhaps to carp esoterically. Yet it is almost a platitude that a review must make a critique. This is a good book. It does not supersede all other such books for two general reasons. First, the single author approach which Allen cited as a *raison d'être* in the first edition has certain inherent shortcomings, *viz.*, the remarks on the wildlife chapter above. Secondly, the treatment accorded some of the most basic conservation issues confronting us today, e.g., population and land use problems, seems disappointing in some places and, to this reviewer, philosophically aberrant in others. The apotheosis of the questionable thesis which permeates several chapters and to which Allen, as a practical man, apparently subscribes, appears on page 213: "There is not much chance to argue against encroachment features if the expanding economy idea is valid, and most Americans believe that it is and that our standard of living must be steadily improved." No one, however, can cavil at the wealth of information packed between the covers.—ERNEST E. PROVOST, School of Forestry, University of Georgia, Athens, Georgia.

Biogeography and Ecology in Australia. Edited by A. Keast, R. L. Crocker, and C. S. Christian. (Monographiae Biologicae, edited by F. S. Bodenheimer and W. W. Weisbach, Vol. 8.) Uitgeverij Dr. W. Junk, Den Haag. 1959. 640pp., illus. $15.00.

Biogeography and Ecology in Australia is truly as broad in scope as the title implies. It is not a book to be read from cover to cover; rather, it is an excellent reference volume consisting of 37 chapters about Australia's scientific achievements

in understanding her biogeography, her fauna and flora, and the ecology of her settlement and development.

The 40 authors who have contributed to the book include many of Australia's leading scientists. Nearly every chapter is a compendium about that author's respective field of interest; and the chapters cover a wide range of subjects in the field of agronomy, animal production, anthropology, biological control, botany, climatology, nature conservation, entomology, geology, geography, hydrology, soils, wildlife management, and zoology. In most instances the subject matter is presented with an ecological emphasis and each chapter includes a liberal citing of pertinent literature. The majority of the chapters will be of interest to the wildlife profession, but those of greatest interest pertain to the marsupial fauna and its ecology, marsupial reproduction (124 references listed), native birds, fresh-water fishes, the contribution of bird banding to Australian bird ecology, the ecology of wild ducks, ornithosis research, and the story of the introduced European rabbit and its partial, but apparently temporary, control with myxomatosis.

I find the remarks about the irregular waterfowl breeding in Australia particularly interesting. Among their common species every stage exists between those that have a regular annual breeding season to those that may breed whenever and wherever conditions are suitable, often changing the time and place of breeding in successive years. Those species that inhabit the permanent, stable water areas have regular breeding seasons. The ecological and behavioral explanations of the different degrees and patterns of mobility which duck-banding has demonstrated are still somewhat speculative; but the rapid colonization of waters, as soon as they are formed, by large numbers of ducks appears to necessitate some positive response which directs the birds towards them, and is not due merely to chance encounter by ducks dispersing aimlessly from unfavorable areas.

The many fascinating problems about the zoogeography and the origin and development of the Australian fauna and flora are discussed. The fauna consists of 108 placental mammals, 119 marsupials, 2 monotremes, 520 birds, about 380 reptiles, 112 frogs, and 180 fresh-water fish. Several chapters point out how isolation on a giant scale has made conspicuous the results of adaptive radiation in speciation and how Australia's prolonged isolation has fostered the greatest phylogenetic development of a single mammalian order, the Marsupialia, the world has ever known.

This volume, Number 8 of the Monographiae Biologicae series edited by the late F. S. Bodenheimer and by W. W. Weisbach, is a valuable reference in the field of Australian biology that should be in all major libraries. And, for many years to come, anyone interested in a review of the ecology or biogeography of this part of the world will find it a must to consult the pertinent chapters in this book.—WALTER E. HOWARD, Field Station Administration, University of California, Davis, California.

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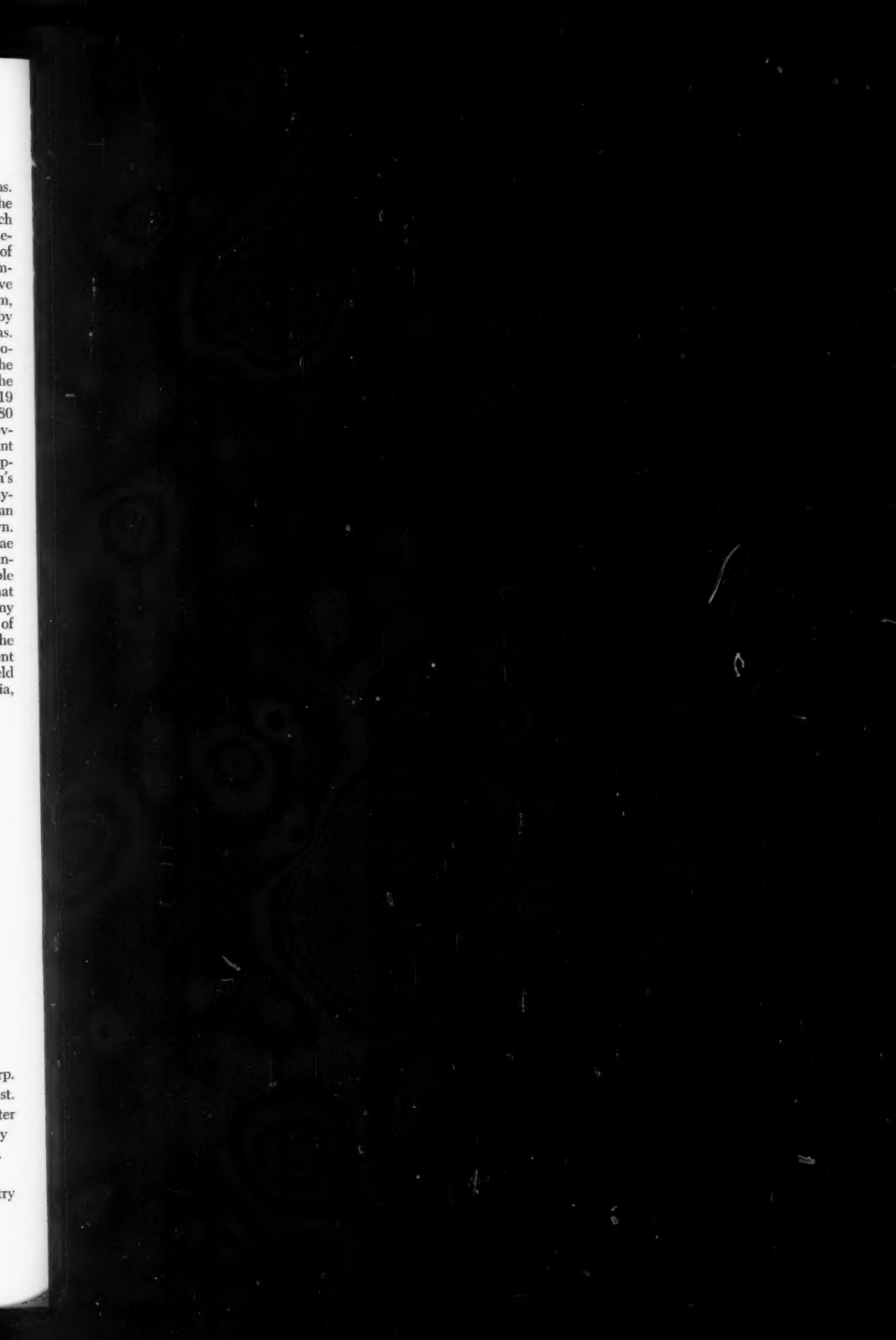

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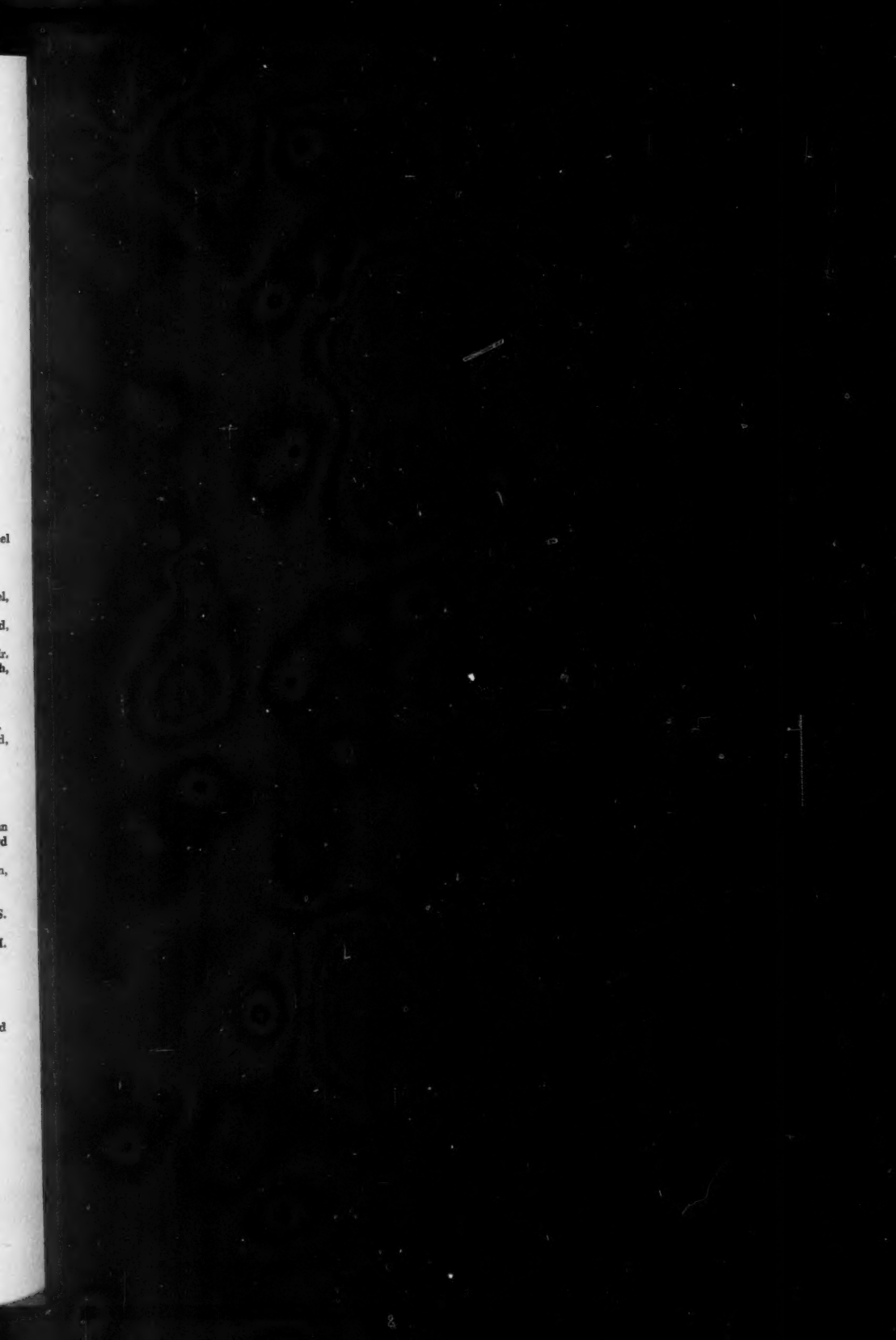
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